THE TIME OF PERCEPTION

and the

CEREBRAL POTENTIALS.

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C O N T E N T S

/SECTION FIVE

CONTENTS (Contd.)

INTRODUCTION

In Manchester, in 1874, Caton first demonstrated that a spontaneously fluctuating electrical activity could be recorded from the exposed animal brain. It was not until 1929, however, that Hans Berger, a psychiatrist, succeeded in recording from the intact skull of a human subject. He called the record which he obtained das Elektrenkephalogramm. The name has remained, and the whole study is referred to as Electroencephalography.

The fact that Berger was a psychiatrist has had two repercussions which have affected the study considerably. He first published in the "Archives of Psychiatry and Nervous Diseases", and his work passed unnoticed until 1934 when Adrian and Mathews published a verification. The second result was that his interest in psychiatry led him to test the relationship between those spontaneous fluctuations and mental events amongst his first experiments. Psychological phenomena, then, have a very important place in the foundations of the subject.

With the verifications of Berger's work by Adrian and Mathews (1934), and Gibbs, Davis, and Lennox (1935), there was reason to be increasingly hopeful that psychology had available a new tool which might be of value in uncovering some physiological correlates of 'mental' events.

The pioneer investigators reinforced this hope by reporting

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change in the electrocortical record when a subject was stimulated, (especially startled), or engaged in mental activity. Bagchi (1936), Knott (1938, 1939), Loomis, Harvey, and Hobart (1936), Travis, Knott, and Griffith (1937), Travis and Knott (1936, 1937), and many others added to the experimental proof of the relationship between the alpha-rhythm as a physiological index, and mental activity.

The correlation of sensation and after-sensation with the alpha activity (the ten per second 'normal resting rhythm') by Cruikshank (1937), Jasper (1937), Jasper and Cruikshank (1937) and Travis and Hall (1938), has shown that some relation exists, albeit inconsistent in respect of sensation per se.

In respect of the establishment of the electrocortical correlates of action, Knott (1939), reports that "it is known by all workers in the field that the effect of a light stimulus is to make the alpha wave more apparent (evoked potential) or less apparent (blocking)". If a subject is given instructions to respond to such a stimulus in some prearranged fashion, there is a change in the aggregate at least, of the time of blocking of the alpha rhythm. The change in the blocking effect is a change in degree rather than kind, and can be detected only by measurement and analysis.

"The investigations have shown that the sentence 'React to the light' or some variant, can alter the response of the alpha rhythm to light even if the instructions are just to

/count

count the number', (Knott, 1939). This sentence gives a clear indication of the possible usefulness of the electro-encephalographic technique in Psychology.

The use of this technique with the Behaviour Disorders has been invaluable but has taken much of the focus from the experimental field in the last decade. Since the end of the war, there are relatively few reports of work done on the E.E.G. and psychological factors, though the publication of thousands of papers in the last few years is evidence of the fertility of the subject for medical and physiological investigation. By so much has the subject fallen from popularity with the psychological laboratory, that we read "normal psychology has received little benefit from the study of electrical brain activity" (Munday-Castle 1950, p.25) and hear Vernon say the same thing (Vernon 1952), a conclusion which would have surprised the earlier discoverers of the activity.

The evidence on the subject of attention and its association, which I shall mention, shows that there are concomittant activities shown upon the E.E.G. The problem is only to decide how to examine the relationship between the two, and to extend the methods into related topics.

The present work is an attempt at showing the value that the electro-encephalograph may have in the experimental psychologist's laboratory, and the way in which new techniques can be developed and may be expected to develop in the future.

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There are two possible avenues to this goal, to develop the techniques individually and separately, or to allow them to arise in the course of the first steps in the solution of a central problem. Both alternatives have advantages. In this paper the latter is adopted, and five exploratory experiments are reported which have a direct bearing on the time of perception. The problem is defined in the next section.

SECTION ONE

Chapter 1

The purpose of this section is to define the major difficulties in the way of the investigation which gives its title to this work.

The problem lay in the results of an investigation by Thurstone (1943), in which a factorial analysis was made of the results from a great number of perceptual tests, and some others, the outcome of which showed that the first and most general factor was that, best described as 'time of perception.'

Being the first factor, the implications are that it is fundamental, and at least as important in perceptual tests as "g" in the Binet type of test. But how to examine further? A factorial analysis is a gross method, and the only way of knowing that the same variable is operating, is by the repetition of a substantial part of the same experiment together with the inclusion of further tests.

Instead, another approach was taken. If the supposition that time of perception is fundamental is correct, then it is a small step to consider that it must be related in some way to the electrical activity of the brain. Adrian (1933), McCulloch (1947), Gerrard (1949), Walter (1950), and others have reported that, if the surface of the cortex is stimulated, excitation waves travel from this centre in all directions (demonstrably through the axons of the cortical neural populace) at an apparently

/fixed

fixed rate, varying slightly between animals and between different human subjects.

An experiment was planned to investigate the possibility of recording this spread. Accordingly, a light of high intensity was used as a stimulus, and the response of the occipital and the occipito-parietal region, two to four centimetres away, were recorded. The presence of characteristic response was detected, but consistent evidence of a phase difference was not obtained.

An indirect method of examination of the problem had to be found, and the method of stimulus and behavioural response seemed to offer the best opportunity, as it has long been recognised that there is an apparently irreducible minimum in the reaction time to which results have 'tended'. However, the inconstancy of reaction time is also well recognised and has beem variously reported as being due to attitude, attention, set, intention, etc.

It seems impossible to eliminate these variables from any reaction in order to examine the minimum time, so a thorough examination of their effects must be made as part of such an undertaking. It has long been known (see Jasper and Cruikshank (1937), Travis and Egan (1938), Travis and Hall (1938), Knott (1939), Loomis, Harvey and Hobart (1936), and others) that there is a change in the cortical excitatory state (represented by the

/electrical

electrical activity) in the stimulus and response situation which is directly recordable. It is reported that this varies with attention. Jasper (1937) equates the two.

The first part of this paper, therefore, is an attempt at delineating the mechanism and experimentally demonstrable variations of the 'automatic' central processes. These are better known as 'set' (etc.) and we can refer to them as non-sensory influences on behaviour. Following this, will be a description of some findings on the relationship between the intervening variables, as they affect time of perception and the electroencephalographic recordings mainly from the occipital and central regions of the cortex.

/Chapter 2

Chapter 2

SET

Under this general heading, I propose to discuss an intervening variable in the stimulus-response situation.

I use the word 'set'. Though it has no unique meaning, it is generally used in the manner indicated in the first paragraph. It is implied, by employing the term, that there is incomplete sensory control over the response.

A considerable amount of the work involving the concepts of 'set' has been done incidentally to other experiments where 'set' has been invoked to explain equivocal results. Little attempt seems to have been made to reach a consistent terminology, and no two writers agree in all their concepts. It was necessary therefore, to make a preliminary classification of all the related concepts from experimental evidence, and to use this as one step in the process of reduction to a working hypothesis. The headings are in no way intended as final, but are merely descriptive summaries not necessarily independent. The end result, it is hoped, will produce a number of separable variables.

/The

The usage of the term 'set' and its equivalents.

There are extensive and intensive reviews in the literature, notably those of Woodworth (1938), and Gibson (1941). Rather than present a repetition of this work, I have made an assessment of some one hundred and thirty experimental papers, etc., representing the most important contributions on the subject. The aim is to ascertain the explicit or implicit experimental variances of the effect 'set', to name them, and later to discuss their relationship to fundamental mechanisms. The references are those of Woodworth and Gibson, and for clearness will be omitted.

Following this, the place of set in some modern systems of Psychology will be dealt with in greater detail.

I have found it necessary to use seven headings; they are attitude, habit, hypothesis, attention, expectation, expectancy and intention. For clarity, the usages given to these terms in the following paragraphs will be indicated in later discussions by placing them in inverted commas, otherwise the meaning given to the word by the writer under consideration will be implied.

Attitude

This word refers to that which writers describe, often very loosely, as the general approach by the subject to the experiment. It is governed by the general personality qualities of the subject, the result of past or immediately past experience and his relationship with the experimenter - verbal instructions an

/and

and so on.

It is very often assumed to be constant throughout the experiment.

In other contexts it is often paired with a modality e.g., sensorial attitude as contrasted with muscular attitude by Woodworth, and refers, in this case, to something of the same order as attitude, but not necessarily to an unchanging, general approach to the experiment.

Habit

This is again an approach, operation or method carried to the experiment as the result of previous experience. It is specific and related to the problem. Usually it is set up by a previous experiment and then the transfer of training tested by success at the new task, as compared with either the training experiment, or the result of a 'control group' not previously trained.

Hypothesis

This is a definite conceptualisation, not necessarily conscious, of an order in the field. The evidence for such a construct is a persistent activity in the face of lack of reinforcement, with the series of results being marked by rather

/sudden

sudden changes; as such, it may be thought of as an 'inertia'.

Attention

This represents the focussing of the receiving organism. It is often used synonymously with strength of fixation (on a problem). Its obverse is distractability, and it is often tested in the latter form. A further facet is in terms of locus or span. These words are not experimentally opposites of focus; they depend upon temporal factors as a result of focus, e.g. span of memory or perception.

Attention is focussed, mobilised, distracted, etc. and is the abstraction made by all workers with reference to the necessary conditions to block the alpha rhythm. Mowrer (1950) refers to it as secondary motivation. Lindsley (1951) places it on the same continuum as emotion.

Expectation

This is the prearoused anticipation of stimulus, stimulus mode, objects, qualities or relations. It might be verbally induced and it is contrasted with -

Intention

- being prepared to react by making specific movements, it

/is

is motor organisation plus motivation. With this variant of set, we get the greatest number of false reactions in a classical reaction time situation. Many writers talk of intention to perform a familiar mental operation (multiplying. memorising, giving the opposite word, and so on). This aspect is extremely similar to transfer of training.

Expectancy

This is not to be confused with expectation. It is the association of one stimulus acting as a "signal" for another (sign-significance). It represents the subjective probability that, at any given time after warning, a certain stimulus pattern will occur. It refers clearly to the temporal characteristics of the situation. It is built up in the experiment, and is labile and transient. ~~and is not verbally induced.~~

The foregoing concepts are not all at the same level of abstraction. Some might be thought to overlap or include others, but they are necessary in the classification and have been shown, under certain conditions, to be experimentally separable. They are not a satisfactory minimum, but were intended as a maximum. As a minimum, Mowrer (1950) proposes that they are all one and the same thing.

I am not in agreement with Mowrer for reasons to be given later, such as that, for instance, attention and expectancy clearly stand out as being of a different order from the remainder. These

/may

may easily be subsumed as forms of attitude, whereas, attention as described, is itself a mechanism, and expectancy is the function of a very specific system; about these differences, I will have more to say later.

Some of the most important contributions on 'set' of the last decade or so are discussed below, in order that I may compare the provisional headings with these ideas.

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Morgan,

Concepts of attention, expectancy, set and perceptual set are used by Morgan (1943), in ways not in agreement with the schema already presented.

Poppelreuter (1917) discovered that patients with small striate lesions (occipital area) show defects of what he calls visual attention. Morgan, in line with Neurology and Neurophysiology, refers to attention in these terms. (cf. Holmes 1946).

The distinction to be made between defects in attention and sensory loss is subtle but meaningful. Objects may be 'seen' well enough but they may not be able to command behaviour. This is the same as saying that a stimulus pattern falling on the part of the visual field associated with the lesion cannot become associated with a response, even if the same pattern falling on another part is so associated. This loss would appear to be one of localised sensory organisation, i.e. 'expectancy'.

/Set

Set, says Morgan, is a property of the central motive state (c.m.s.); it is a potentiality for presenting various patterns of behaviour when the appropriate stimulus conditions in the external environment are available. A hungry animal eats when food is in front of him, but does not exhibit mastication and so on, in the absence of food. He goes on to say that, in the absence of the appropriate external conditions the c.m.s. can be said to prepare, prime or set the organism for these forms of behaviour when they become possible. We are dealing here with motor organisation associated with (conditioned to) a motivation which I have referred to as 'intention'.

The central motive state has three aspects, general activity, specific activity, and a readiness to perceive and react to stimulus situations in particular ways. They are an effective way of remedying the condition which motivated the animal. The priming aspect is most important (sic), it makes behaviour appear purposive, and determines the habits learned in obtaining the state of satisfaction. Morgan reports ablation experiments which show that the set aspect of motivation (i.e., the c.m.s.), is dependent upon the presence of the intact cerebral cortex. Without the cortex the c.m.s. eventuated in only the general and specific forms of behaviour. This is very similar to the effect of frustration on the young animal and provides some evidence that "intention" ('set' in Morgan's terminology) involves learned organisations.

/Hilgard

Hilgard and Marquis (1940) remark that expectancy was introduced into learning theory to account for the phenomena of learning not otherwise explicable in terms of substitution or trial and error. This is illustrated in Tinklepaugh's experiment (1928) with monkeys. Bananas were the usual reward, and on being unexpectedly given lettuce in place of the bananas the animals rejected it, in spite of the fact that lettuce is normally acceptable. Morgan's concept of expectancy is in agreement with this. He goes further, however, and says that he regards it as a central neural process, which stands for the successful act and serves the same function; it is to him a secondary principle deriving from the principle of effect. Expectancy, he says, is of the act for which the motivation primes the organism. By definition it is therefore a symbolic process.

The symbolic processes are divided into four headings by Morgan. First, trace processes which represent previous sensory experience and are illustrated by the delayed reaction experiments. This appears to be similar to "expectancy" in my scheme. Second, expectancy; Morgan refers to expectancy as probably a complex cortical process involving neural activities representative of previous experience, (i.e. trace processes), plus a set or preparation for particular types of response ("expectancy" plus "intention"). The third and fourth are seratim aspects of symbolic function and reasoning respectively. Reasoning is said to involve symbolic trial and error together with the other three

/aspects

aspects.

We are here concerned with the first two headings. Morgan presents evidence that trace functions depend upon frontal areas, in so far as a set (in his use) is required in reacting to them, but the traces themselves can be mediated elsewhere (ablation experiments with monkeys). The trace represents the sensory rather than the motor side of adjustment, and Morgan concludes that the sensory (trace) aspects of symbolic processes are mediated primarily in the more posterior parts of the brain. The best information available concerning aphasia would seem to fit this conclusion.

Expectancy (Morgan's use) is located in the frontal lobes. It has been directly tested with rats, and evidence from experimental neurosis in monkeys, leads Morgan to believe that if direct tests of expectancy are carried out on monkeys then they will clearly indicate expectancy to depend upon the pre-frontal areas.

Seratim function is a complication of the simple intention and this has been proved unequivocally to be dependent on the pre-frontal areas in monkeys. (It is defined by Morgan as that capacity to organise and sythesise motor activity in serial order).

He concludes that the fundamental functions underlying symbolic processes are of two sorts, trace (imagery) and expectancy (intention). ("One might also call them sensory and

Motor

motor or receptive and expressive" p.558).

In summary then, Morgan uses concepts of "intention" and "expectancy". There exists physiological evidence of their existance and their localisation. "Intention" is localised in the frontal lobes of the cortex. It is intimately related to motivation and motor organisation. "Expectancy" depends upon the intactness of the striate area and might be called sensory organisation.

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It is perhaps pertinent at this point to consider the work of the clinical neurologist. I have taken Holmes (1946) as an example.

Holmes considers that attention is the focus in the conscious field. It is responsive to stimulation (stimuli or thoughts may hold it) but it is directed away from these things by "will" (concentration is his example). One of the most important of neurotic symptoms is lack of attention. The power of focussing attention on any part of the body depends upon the integrity of that part of the cortex in which the sensation is represented.

A local defect in attention may result from a cortical lesion. For instance, (as Morgan also points out) a defect of local attention in the visual fields is well recognised. It becomes very obvious when stimuli of equal intensity are applied simultaneously to the affected and normal parts. Very few, or no responses, may be obtained from the former, though, when tested separately, no defect in sensation can be discovered in it.

/Attention

Attention hemianophia is apparently caused by hysteria, exhaustion and non-specific cerebral lesions. "It is especially noticeable in a long clinical examination when the patient is tired or his attention is distracted".

This appears to be a case of dominance and might well be evidence for a "mass action" hypothesis. Trace processes ("expectancy") appear to be interfered with, but in the earlier definition a mixture of "expectancy" and "attention" (in my schema) seems to be implied.

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Hebb

Hebb (1949) defines attention as a central facilitation of a perceptual activity and says that, so used, it has the same meaning as perceptual set. (p.102). That he does not think of the identity unequivocally is evidenced by the statement (p.153) "Perceptual set is.... closely related to attention", though there is sufficient overlap for the definition to stand.

He opens his discussions of attention and related topics by making a very strong case for the necessity of taking this non-sensory process into account.

In different contexts he uses the terms attitude, set, attention, expectancy and anticipation. Since he devotes the greatest amount of space to attention, I will commence with this.

In the introduction (p.6ff.) he states the facts pertaining to the existance of autonomous central processes, and bases a great deal of his argument upon the presence and absence of the alpha

rhythm and the studies reviewed by Jasper (1937).

He writes as if he assumes that sensory processes per se are the cause of blocking of the alpha rhythm; his conclusion does not depend upon this assumption, however, and it is that the alpha rhythm is evidence of non-sensory activity in the brain. Attention selects from a given sensory input, it refers to the selectivity of response. He writes, "A subject may not remember that to which he did not pay attention."

In terms of Hebb's notation, activity in the cell assembly a facilitates the arousal of the assemblies b and c, as well as the motor response to fixate B and C. When B is looked at just after A, activity in b is aroused in two ways, sensorily by looking at B and centrally by association of ideas. The central facilitation from a is an instance of attention. This represents an enduring trace of not only a, but b, which is normally present close to a in time, due to their sensory closeness, and, therefore, centrally close after 'learning'. This is clearly the same as "expectancy". (In Hebb's neurophysiological exposition, A, B, and C are the points of a triangle and a, b, and c are the respective cell assemblies. They are learned.)

Attitude is contrasted by Hebb, 1) from the more briefly lasting attention ("expectancy"), 2) from the stable selectivity that may be either inborn (instinct) or established by slow learning and remains unchanged from one day to the next (habit). He links attitude with intention and interest and refers to it as the per-

/sisting

persisting central neural influence that sustains activity in one direction. Attitude is non-sensory but it is a conceptual cycle (to which sensation must continually contribute). This might occur he thinks, by having classes of associated cortical activities, e.g. as a result of having occurred together frequently, each activity in a class A, B, C, D, ... would facilitate other activities in the same class so that we get in sequence A-B-C-D-A-B-C-D .... which would have a greater maximum duration than the smaller cycle A-B-C-A-B-C- ... (Each letter in this case stands for a conceptual activity or phase cycle, not a cell assembly action. Phase cycle subsumes perhaps many cell assemblies).

Expectancy is used in two ways by Hebb.

1) If the initiation of one of the above protracted and selective series involves some lasting bodily condition, such as lack of food, which in the presence of a particular environment sets up an expectancy of eating, the expectancy might dominate the series and have a further organising influence. In this context Hebb is talking of expectancy used in the way the older writers used "intention", and as I have described it. For example; in the above case we have lowering of the limen determining eating. A then stands for expectancy of eating and a series might be A-B-A-C-A-D-A .... with A dominant.

2) the second use of the term emerges as follows. In the last paragraph we talked of the expectancy of eating. Hebb also talks of expectancy of food. This seems to have a different connotation,

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and reminds one of Tinklepaugh's experiment (see under Morgan). Hebb gives the example involving the phrase, "A rat in a maze when it has reached point A → perception of C → expectancy of an alley leading towards F...." and so on. This appears to be synonymous with his use of the word attention and to have the same meaning as I gave the word "expectancy".

After further trials of the above, i.e. greater learning, Hebb uses the word anticipation, e.g. we have perception of A → expectancy of food with orientation towards C → anticipation of C. Anticipation might be referred to as memory in this context.

In summary then, Hebb uses attention, perceptual set and expectancy of sensation (second paragraph on expectancy) as synonymous, and in the same way as my use of "expectancy"; attitude also is used in the same way as outlined for it; to Hebb it seems to be an integration of "expectancies". If there is motivation, then we may have expectancy of doing something (first paragraph on expectancy) in Hebb's terms, or "intention" in mine.

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Mowrer

Mowrer (1940b) quotes the early introspectionists in that "anticipation is usually accompanied by strain". This he equates with expectancy.

Following Ach of the Würzberg school, Mowrer says that the difference in the latency of a simple reaction, such as releasing a key in response to a light or tone (human subjects) when the

/stimulus

stimulus is presented without warning, contrasted with a reaction before which a preparatory signal was given, clearly shows the role of expectancy or preparatory set (attention) in determining the time required for such a reaction to occur. He implicitly assumes that the relation between expectancy and quickness of reaction is continuous, and explicitly proposes to assume it linear until proved wrong. His experiment tests expectancy from moment to moment as a result of previous (immediate) stimulus and response.

His results show a characteristic reduction in reaction time as the 'expected' interval between preparatory signal (in his case, the last stimulus) and the stimulus is approached

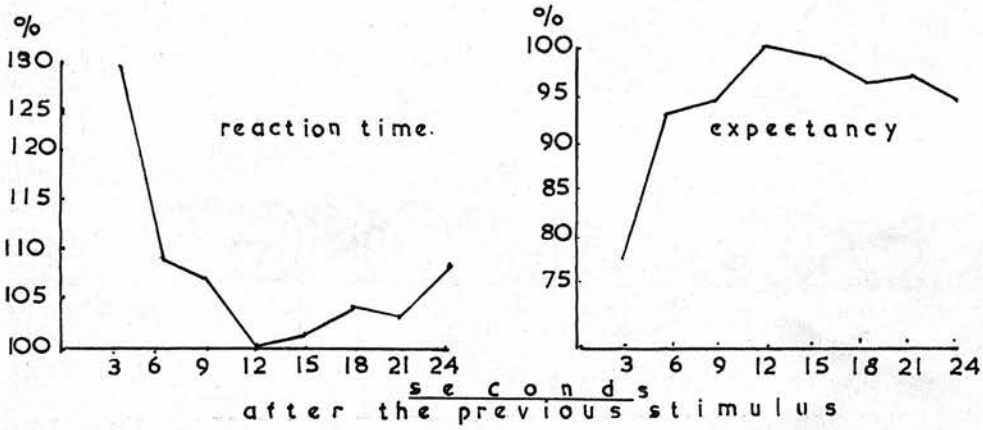

FIGURE I

In the figure, the left-hand side curve represents reaction-time in a percentage of the minimum, and the right hand side curve the inverse, which he defines as expectancy.

It is believed, he says, that the general shape of this curve, involving a relatively rapid rise to the maximum point and then a

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more gradual decline, can be derived from the concept of stimulus traces and from the principle of generalisation of conditioning.

Mowrer takes the view with Jasper (1937), that the blocking of the alpha rhythm is due to the central excitatory state, and equates it with what he calls expectancy. Other experimenters, using the technique of electroencephalography, refer to the blocking as the organism 'being excited', 'aroused','emotionally tense', 'very alert', 'intense concentration (of attention)', 'attending', etc. The evidence for Mowrer's assumption is that a preparatory signal can take on the properties of causing blocking, after being paired with or preceding a stimulus which will itself cause blocking, on a number of occasions. This fact is extremely well-supported by evidence from many writers.

Mowrer insists that "preparatory set (expectancy), attention and the like are in fact the same thing", (Mowrer 1940). In spite of this he places a twofold emphasis on the interpretation of his results. This may be seen by examining his contribution in 1941 and his monograph 1940b, and later, his comment on the reprint of this monograph in 1950. In the first case, he is intent on establishing the central locus of preparatory set (expectancy). When looking for a mechanism he talks of set as a conditioned stimulus, although elicited by a stimulus which necessarily precedes it, it is basically anticipatory. By the process of conditioning, the affected organism learns, on the basis of past experience, to make adaptive adjustments to

/impending

impending (future) events. Sets, therefore, may be thought of as implicit conditioned responses. As an illustration, he refers to the conditioning of the alpha rhythm (p.131). However, in the monograph, we find expectancy (etc.) referred to as a state of tension or discomfort involving anticipation of the recurrence of one or more needs. In his book (1950) he says, "As indicated in Chapter One, all emotions have an expectant or anticipatory quality, and are sets for one form of activity or another." Expectancy is referred to as secondary motivation.

Previously he had attributed two facets to the problem of preparatory set (expectancy). On the one hand, as an explanation of a variety of behaviour changes which are often mistakenly attributed to learning, but which are really due to the mere tripping of an existing state of preparatory tension. On the other hand, set was considered as a motivational factor. By this postulation, the law of effect, as reformulated by Thorndike, can be made more acceptable as a universal explanation of learning, applicable no less to the conditioning of defensive reactions than the formation of new habits by trial and error, and more obvious forms of goal-seeking behaviour. Mowrer suggests the universal principle is that learning occurs when a reaction system which has been under tension undergoes a tension reduction. As we shall see in the discussion of set and learning theory, he retracts from this universal principle and accepts a two-factor theory of learning in 1947. This change appears to make very little difference to his

/notion

notion of set, since he is still taking of set as a secondary motivation in 1950.

In spite of the variations of emphasis, there is no logical antithesis here. The later ideas (set as secondary motivation) are similar to that which I have called "attention". However, his experimental work is not entirely consistent with these ideas. The experiments involve a stimulus at regular intervals to which the subject releases a key after which he presses it again. Thus, the last stimulus acts as a preparatory signal for the next. This, I consider, is better fitted to my exposition of expectancy. It seems to me that, at any given instant, "expectancy" of the next stimulus may be rising, whilst "attention" may wander at random. Furthermore, when the stimulus does occur, it will not have the property of attracting "attention" for just that reason, that "expectancy" was high. Some evidence of a concrete anatomical difference between the two was given in the section on Morgan, and I will take up the point in the next part of this paper.

Attitude is referred to by Mowrer in terms of a limiting of the behavioural response in Calvin's experiment (1939). He talks of a negative attitude and seems to use the word in the same way as I have used "habit".

To summarise, Mowrer considers theoretically that attention, attitude, preparatory set, etc., are equated. In general, he describes them in the same way as I have described "attention".

Chapter 3.

LEARNING THEORY AND SET

Set has played an often changing role in learning theory. The early students of human conditioning contrasted the two, so that when the subject reacted and was not conditioned he was said to have a 'set' (Scholsberg (1932), Gason (1934), and Razran (1935)).

The Watsonian school rejected any such intermediary and posited only sensory control of the reaction. In the same line the later stimulus-response (S-R) theorists, by laying stress upon the response, refer to set as being a conditioned response. (Hull (1929, 1931), Hunter (1938), and Hunter and Huggins (1934),). In contrast, Tolman (1932, 1937), Tolman and Brunswick (1935), and others including Zener (1937), who lay stress upon the 'S-S' (signal or replacement characteristics of the conditioned stimulus) relationships, say that conditioning is set. The difference is not entirely verbal. 'Set' to Hull is 'habit' or 'intention' in my terminology, depending upon its performance; to Tolman it is 'expectation', or 'expectancy' in my terminology depending upon whether it is permanent semi-permanent, or transient. Tolman refers to it under the unified title of expectancy. That these two ('intention' and 'expectancy') are experimentally separable was demonstrated by Linder (1938), and Schilder (1929), and two experiments from Hilgard's laboratory (Hilgard et al. 1938a and 1938b), differentiate them in relation to conditioning. In one (1938a) the subjects are given knowledge of the stimulus relationships, in the other (1938b) the subjects were

/divided

divided into two groups and given "sets" to react or not to react to the stimuli.

The results for this procedure show that the two kinds of ~~attitude~~ state induced are quite different. The authors observe that the control of response by expectancy of stimulus objects, is not to be confused with control of response by specific intentions.

Hilgard and Humphreys (1938c), conclude that a habit, although aided by verbal expectancy during acquisition, may become established at a non-verbal level. (An automatic conditioned discrimination of the eyelid response was found to be retained over a period of four to nineteen months, despite an almost complete verbal forgetting of the stimulus relationships).

Mowrer, as indicated, considers expectancy as a secondary motivation, a tension (1938, 1950) and it is therefore an intermediary in conditioning (itself being an implicit conditioned response) but clearly in a different sense from Hilgard and Humphreys.

Although a rigorous treatment of learning theory is beyond the scope of this paper, the dependance of learning upon set and vice versa is an explicit assumption.

The necessity for concepts of set, etc., has been demonstrated by learning theorists in the last decade, and as the expositions of the writers Morgan, Hebb and Mowrer have shown, the non-sensory activities of the cerebral cortex, as far as they influence organised behaviour, are themselves to some extent learned, i.e. the result of

/the

the temporal contiguity of two stimuli.

It is pertinent here then to discuss the relationship between the principle sub-divisions of learning theory, and the concepts which have become subsumed under the heading set.

The theories of learning may be classified (after Spence, 1951) -

1. By the nature of the fundamental concepts (intervening variables) employed to represent the hypothetical changes which take place in learning (S-S versus S-R).
2. According to the conditions necessary for the hypothetical learning changes to take place (law of effect versus contiguity).

The first classification shows the difference between the sign-significate on the one hand, and the stimulus-response theories on the other.

Köhler (1929, 1940), Koffka (1935), Lewin (1936), Tolman (1932, 1934), Adams (1931), Zener (1937), and others including Hebb (1949), take the position that learning takes place in terms of organisation (or re-organisation) into some kind of functional whole, of the perceptual systems of the subject. In this case any concept of set is said to interact with the ingoing sensation.

In sharp contrast is the conception that is held by the other group, e.g. Thorndike (1935), Hull (1943), Guthrie (1930, 1935), Miller and Dollard (1941), and Spence (1936), that learning is to be conceived in terms of alterations of the strengths of hypothetical intervening variables. In this case, set, if discussed at all, is

/such

such as to cause an otherwise unpredicted variation in the response - the output - of the organism (intensity of response very often).

In summary, we might say that the S-S theorists emphasise content of material learned, whereas the S-R theories pay more attention to the temporal relations of the response. The latter make little mention of the word 'set' or its associates. Unfortunately it has mentalistic connotations. They might talk of it as a tendency or a habit to react in a certain way after training, or it might be referred to as the goal directing function of a central activity. This is 'intention' and it disappears, as mentioned under Morgan, with the ablation of one-third of the prefrontal area in rats and monkeys. There is also clinical evidence for the same sort of defect after prefrontal lobectomy in man.

The sign-significate theories in stressing sensory events resulting from the conditioned or unconditioned stimuli, refer to set as a perceptual organising process. For instance, Lashley (1942) talks of the mechanism of nervous integration and says that "...it is such that when any complex of stimuli arouses nervous activity, that activity is immediately organised and certain elements or components become dominant for reaction whilst others become ineffective. This constitutes a set to react to certain elements..

In any trial of a training series, only those components of the stimulating situation which are dominant in the organisation become associated."

Contrasting the effects of lesions in the occipital region

/with

with those of the frontal region, we find that both are said to affect set or attention. From the occipital region lesions we have interference with trace processes, i.e. "Expectancy". From the pre-frontal region, inability to carry an "intention" of the appropriate reaction if it is delayed, or to carry out a quick reaction. Harlow and Johnson (1943) report an experiment in which a piece of food was exposed to the experimental animals for a given number of seconds; if they did not take it in the time, they lost it. Both normals and pre-frontal animals can do it within all reasonable time intervals, but there is a considerable difference in success when the interval was just one second long. The normals could react and get it, the pre-frontal monkeys could not.

The second classification, the reinforcement - non reinforcement (contiguity) case, contains three positions.

The first, that learning requires some motivating state, primary or secondary, and the occurrence of a reinforcing state of affairs (drive reduction). Thorndike's initiation of the law of effect has been more closely adhered to by Hull (principle of reinforcement), than by Thorndike himself. Mowrer also (up to and including 1946) said learning depended upon drive reduction.

The second group of psychologists Tolman (1937, 1938), Lewin (1942), Guthrie (1935, 1942), and Rexroad (1932, 1933), share the belief that reinforcement is not necessary for learning to occur. They recognise as important, frequency, recency and contiguity.

/The

The third position is a compromise. Thorndike (1932, 1935), Schlosberg (1937), Mowrer (after 1947), Skinner (1938), Razran (1939), and Stevens (1942), hold that there are two basically different learning processes, one to which the law of effect applies and the other in which contiguity is sufficient. Skinner and Mowrer, for instance, hold that classical conditioning responses (involving skeletal muscle) are mediated by drive termination, but emotional conditioning, involving responses controlled by the autonomic nervous system, is not. There are indications in Mowrer's earlier (than 1947) work as well as in his book (1950), that he considers emotional conditioning as the first stage of an avoidance learning. After two or three trials, an aminal approaching a grill, from which it has previously received a shock by contact, shows marked fear, anxiety, or avoidance reactions (flattening of ears, stopping, crouching, etc.,). This is anticipation with the visual stimulus complex as a sign or conditioned stimulus. After more trials it learns to jump the grill. Had there been no set, anxiety, fear, expectancy, etc., as a conditioned secondary motivation, it seems unlikely that the animal would have learned to jump over the grill.

The work of Brogden (1939, 1947), and Karn (1947), on sensory pre-conditioning lends support to the idea that stimuli can be associated without motivation. Since it is also undoubtedly true that under some situations drive reduction is necessary for some forms of learning, it would appear that some

/dual

dual concept is necessary and that the third position is the most reasonable.

Chapter 4.

DISCUSSION

Two things are abundantly clear from the last chapter; first, that the seven subdivisions of the concept of set are more than enough to satisfy the experimental evidence; and, secondly, that no single writer considers all the aspects which have at one time or another been studied. None of them uses the words to signify the same group of concepts and a clarification is long overdue. This was attempted by Woodworth (1938) after his summary, and he makes the most of the experimental evidence pertaining to the difference between 'expectancy' and 'intention'.

Since Woodworth, Mowrer, who has written perhaps the most about set in the last decade, has repeatedly reiterated the oneness of the mechanisms underlying set in all its variations. Here we have a dilemma; the evidence which Woodworth uses is good and acceptable in the light of all the evidence quoted here; therefore it is necessary to examine the accuracy of Mowrer's statements concerning the nature of the variations of set, in order that I might establish not one, but some number less than seven different mechanisms.

In the latter half of his monograph (1940b), and its reprint,

/Mowrer

Mowrer discusses the relationship between the E.E.G. and expectancy. He almost makes the point for me. He quotes the truism that when a stimulus occurs unexpectedly with a 'startle' effect, it is more likely to depress the alpha rhythm than the same stimulus after having been repeated a number of times (twice is often enough with auditory stimuli). He asks -

> "Does not such a finding show, contrary to the foregoing hypothesis, that the more a stimulus is expected the less the effect it is likely to have upon the alpha rhythm? This apparent dilemma breaks down when it is recalled that the statement that a person is adapted to the occurrence of a given stimulus event, is not the same as saying that he expects it. As the term expectancy is employed in the present paper, it implies a state of active preparedness for a given type of stimulus-response sequence. Adaptation is the antithesis of this. It implies that a particular stimulus or stimulus situation has lost its 'meaningfulness', that the reaction formerly made to it has, in conditioned response terminology, become extinguished. Thus the statement that an unexpected stimulus is especially likely to be followed by a depression of brain potentials really means that such a stimulus is especially likely to be meaningful to the subject i.e. especially likely to arouse a state of expectancy in a way that an 'adapted' (extinguished) stimulus can not."

The arugment hinges upon the concepts of adaptation and meaningfulness, but is quite consistent with his views as stated elsewhere, provided that for expectancy we read 'attention' in my meaning of the word.

Mowrer's experimental determination of the course of expectancy between successive stimulus events that occur at regular intervals was made by the reaction time technique.

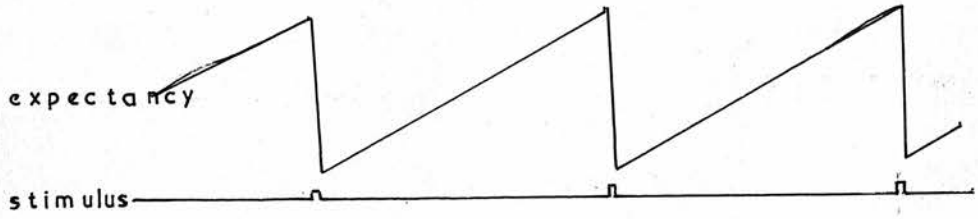
An ~~light was flashed~~ auditory stimulus (tone) was given at regular intervals (12 seconds) and the subject instructed to respond as quickly as possible to each stimulus by releasing a previously pressed key (thus extinguishing the ~~light~~ sound), /and

and then pressing it once more. After a certain number of stimuli, randomly chosen, a stimulus was displaced, instead of following at a 12-second interval, it came at one of the following intervals : 3, 6, 9, 12, 15, 18, 21, or 24 seconds, after the previous stimulus. This was repeated in random order. The curve given in the earlier discussion of Mowrer's work was obtained.

This result confirms Mowrer's hypothesis that expectancy drops markedly immediately after the last response (cf. the 3-second interval), and then rises slowly to a maximum at the point of time coinciding with the next standard interval. (The remainder of the curve shows that if there is no response at the standard interval, the expectancy drops slowly).

Mowrer hypothesised an a priori pattern which fits the case where the subject responds at each stimulus.

FIGURE 2



If this marks expectancy and if, as he says, it takes a few trials for this to be built up, the question arises as to whether the subject has become adapted also? The subject certainly expects the stimulus at certain moments and would not be startled by it, especially if it occurred after one standard interval when (see figures) expectancy will be at a maximum. How then can expectancy

/and

and adaptation be opposites?

The 'startling' stimulus arouses expectancy, he says! But, from the experimental evidence, the repetitive stimulus arouses it slowly during the 'expected' interval. In the limit, an unexpected stimulus is one completely new to the subject, it therefore can have no meaning if it has no associations.

An interpretation of the quotation (previous page) which makes it accurate, is that an emotional response will block the alpha rhythm and this does not occur with the expected stimulus (see Lindsley 1951, and Hebb, 1949, p.148).

Some discrepancy exists then between Mowrer's theoretical discourse and his experimental findings. A second point - in his papers reaction time is assumed to be a good measure of preparatory set. Also, the cortical excitatory state - the negative correlate of the alpha rhythm (Jasper) - is said to be identical with preparatory set. Therefore, we would expect a perfect (or very high) correlation between the latency of blocking of the alpha rhythm and reaction time.

In Table 1, the results obtained by a number of different authors are summarised. The data in the second line of section 3 show that a close correlation was not obtained between latent time of blocking of the alpha rhythm and the reaction time to a visual stimulus (light).

I will add a footnote and a rider to the table.

The first thing we notice is that the greater the number of

/trials

T A B L E I

		KNOTT (1939)	JASPER and CRUIKSHANK (1937)	TRAVIS KNOTT and GRIFFITH (1937)	LOOMIS HARVEY and HOBART (1936)	BAKES (1939)
	STIMULUS	Light	Light	Light	Light	Sound
I	Average time of blocking (seconds)					
	A. With no overt response	0.27	0.28	0.287		0.39
	B. With response after discrimination	0.24				0.32
	C. Speed response					
	(1) without preparatory signal	0.21	0.28	0.248	0.16	0.29
	(2) with preparatory signal		0.20			
II	Average reaction time (seconds)					
	as B.	0.53				0.45
	as C. (1)	0.35	0.45		0.36	0.29
	(2)		0.25			
III	Correlation between I and II					
	in B.	-0.014(.07)				0.6(.03)
	in C.	-0.05 (.07)	0.37(.09)		0.26(.07)	0.17(.04)
IV	Number of trials					
	in B.	642				195
	in C.	796	41		80	391

(Figures in brackets are standard errors.)

trials, the smaller the correlation coefficient. Secondly, none of the writers states how many subjects were tested, and an important point seems to arise from this fact.

It is clear that expectancy as defined from the reaction time experiment, is not identical to the central excitatory state. However, all workers agree that focussing attention upon meaningful material will block the alpha rhythm. Now, if a considerable number of subjects were used, even as few as five or six in Jasper and Cruikshank's or Loomis, Harvey and Hobart's experiment, then only about ten responses would be obtained from each. In this case quite different phenomena would play a predominant role in the correlation coefficient. At the beginning of the experiment, subjects would be more excited, perhaps more apprehensive, and certainly less expectant of the stimulus for a greater proportion of the stimuli than in Knott's experiment, that is, the response would be more the result of conscious attention. Bakes' results with a sound stimulus raise some questions. We know that the effect on the occipital alpha rhythm is more labile and very easy to extinguish. Bakes reports that in only 74% of the discriminatory, and 47% of the speed reactions, did the blocking precede the overt reaction. It seems that the high correlation between the discriminatory reaction time and the concomittant time of blocking of the alpha rhythm, might well be decreased or increased at will by making the discrimination easier or more difficult, and thus calling for less or more attention respectively.

/Whichever

Whichever way this question may be solved, the most important result from Bakes experiment is that the lack of consistency between reaction time in the speed reaction and the time of blocking of the alpha rhythm, extends to other sensory modalities as well as to vision. (The speed reaction, it will be remembered, is Mowrer's measure of preparatory set). The correlation of 0.17 is scarcely proof of the identity that Mowrer suggests.

Here, it would appear, is evidence of an experimentally definable difference between two aspects of expectancy, as it was defined by Mowrer. This does not mean, however, that the objective state of affairs is so clear.

By definition, a preparatory signal is bound to increase "expectancy" of the stimulus and thus reduce the reaction time. In Table I section II, there is an example from the data of Jasper and Cruikshank (1937), and from their experiment, (see Table I section I) a preparatory signal reduces the latent time of blocking. This may be based on too few trials to be significant. On the other hand, Jasper and Cruikshank do not give the number of trials used for the time of blocking, and it is not possible to avoid the fact that there is an indication that alpha blocking and reaction time can be related in some way at least, at certain times, or as a result of certain experiences.

Therefore, the inequality pointed out above may only indicate that the two aspects as defined by Mowrer, are not accurate extensions of the fundamental factors, and it really says very

/little

little about these factors. However, most writers who consider the question at all conclude that expectancy (sensory organisation) is a necessary concept, and that there is adequate reason to believe in the presence of a mechanism in the occipital area to account for it. (See, in particular, Morgan (1943), Hebb (1949) and Popov (1950). The other part of Mowrer's concept, the motivational aspect, I have called "attention". This is recognised as an important factor of set by all writers who variously describe it as a primer, task, tension, the central motive state, and so on. Attention then may be regarded as being both behaviourally and physiologically real.

In this paper an accurate experimental assessment of the interrelationship between these two variables will not be made. However, it is necessary to test the above conclusions and present evidence that the two are separable. The problem is to make an experimental examination of expectancy, defined, with Mowrer, as a function of the reaction time in relationship to attention.

The difficulty of estimating attention is solved if the alpha rhythm is the negative correlate of attention, as many writers including Jasper (1937) have concluded. The next section of this paper will attempt to answer the two questions. Is it reasonable to assume that the alpha rhythm is the negative correlate of attention? If so, how does the temporal course of expectancy (from Mowrer's experiment, see page 33 above) and that of attention compare?

/Summary

SUMMARY

In this section it was decided that the time of perception must be considered in connection with the factors of attention, perceptual set, intention and the like. The literature was examined in order to ascertain the necessary and sufficient variables which, intervening between the stimulus and response, result in behaviour not following the characteristics of the 'Learning Curve'.

Seven headings were found to satisfy the concepts used by the many writers on 'set'. From the experimental evidence, some number less than this would seem to be sufficient. Mowrer considers that one only is necessary. Evidence and discussion were presented to show that at least two, and possibly three or more different mechanism must be considered. Two questions emerge : 1) Is it reasonable to assume that the alpha rhythm is the negative correlate of attention? 2) How does the temporal course of expectancy vary in relationship to that of attention?

SECTION TWO

Chapter 5

The factors which operate to reduce the alpha rhythm

The suggestion made by some writers, that sensation is sufficient will be considered first. The evidence is as follows: (1) Systematic and consistent changes of sensation occur without change of brain waves. A single tone affects the alpha rhythm in 10% of a series of discrete stimuli, (Travis and Egan, 1938).

/It

It completely loses its effectiveness after a number of repetitions (Bagchi, 1936, Forbes and Andrews, 1937, Shagass, 1942, Lindsley, 1938).

The same effect occurs with a light stimulus, but after many more trials, (Knott and Henry, 1941).

(2) Changes in the alpha rhythm occur without sensation. Subliminal light is effective in causing blocking (Cruikshank, 1937, Travis and Egan, 1938).

(3) The response of the alpha rhythm to a stimulus can be varied more or less at the will of the experimenter. The blocking, due to a light stimulus with a paired auditory stimulus was, after a number of trials, found to be elicited by the sound alone. (The sound had previously been presented by itself and no effect upon the alpha rhythm had been observed). Under certain conditions it is known that there are perceptual changes of tone due to its presentation simultaneously with a light stimulus. This, however, could not have been sufficient to account for the results in this conditioning experiment. (Travis and Egan, 1938, Knott and Henry, 1941, Jasper and Shagass, 1941).

Physiological correlates of sensation are not revealed by the alpha rhythm. Changes in the alpha rhythm may occur due to stimulation without any change of sensation, and changes of the alpha rhythm may occur without any change of stimulus. They must vary independently.

What factors do operate to reduce the alpha rhythm? What

/physiological

physiological evidence is there?

Adrian and Matthews, 1934, Berger, 1937 a and b, Knott, 1939, Kreezer, 1938 and Travis and Hall, 1938 report that the heart rate is increased and the conductance of the skin is increased in states when the alpha amplitude is reduced. This is confirmed by Darrow et al, 1942, Freeman, 1940, Forbes and Andrews, 1937 and Hadley, 1941.

When the increases are protracted into chronic conditions we have tension or anxiety, which is found to be associated with low, fast activity in the E.E.G., i.e. low alpha level, (Brazier et al, 1945, Gibbs et al, 1940, Lindsley, 1944) and with low palmar resistance, i.e. high conductance due to sweating, in the G.S.R., Darrow, 1936. Both have been associated with increased metalolism, Hoagland et al, 1938.

The E.E.G. potentials, under conditions of bodily change, are reduced, therefore cerebral activity is increased, and we find that the correlations under conditions of excitation are negative (e.g. heart rate and alpha level - 0.33).

The correlations are reversed in sign in the absence of stimulation. Hadley, 1940, found a correlation of + 0.33 between heart rate and alpha levels under these conditions. Darrow, Pathman and Krönenburg, 1946, found exactly the same correlation, + 0.33. The latter also found that the correlation between the G.S.R. and the amplitude of the alpha to be + 0.38 (± .07) in the resting state. These correlations indicate that both sympathetic

/activity

activity and inhibition of parasympathetic activity, are associated with the increase of alpha potential. A synergistic action is demonstrated which is understandable in that sympathetic activity and inhibition of parasympathetic activity, both increase the tone of the cerebral blood vessels, and that increased tone in these vessels tends to accompany increased E.E.G. potentials, Darrow et al, 1942, 1944, 1945. The decreased cholinergic facilitation of neuronal transmission with reduction of fast or sharp waves, doubtless contributes to the effect, ibid, 1944, 1946.

The correlations under conditions of excitation are negative. Since this is so, the positive correlations in the resting, steady state indicate a subcoritcal preponderance over the effects of cortical functions, if not a degree of actual subcortical domination of the cortex, ibid, 1946.

The same writers conclude that cortical and subcortical influences mutually oppose one another in the E.E.G., i.e. on the alpha rhythm, since resting, we get a set of correlations opposite in sign to correlations produced in conditions of cortical excitation.

Other factors contributing include (a) Carbon dioxide level which, as it increases, causes a decrease in frequency, Darrow et al, 1944, Gibbs and Gibbs, 1941, Gibbs et al, 1940, and produces a vaso-dilation of the brain, Schmidt, 1936; (b) Acidity and the related changes in the level of positive and negative D.C. potential of the brain, Dusser de Barenne and McCulloch, 1939,

Jasper, 1937, and (c) the concomittant utilisation of glucose and oxygen, Hoagland et al, 1938.

It has been asserted in the course of earlier discussions that the blocking of the alpha rhythm depends upon the operation of any factor which will take the subject out of the state of relaxed wakefulness.

Travis, Knott and Griffith, 1937, found that in a drowsy subject, the latency of blocking was considerably longer than with the same subject, later in the same day, when he was wider awake. They also report a depression of the alpha rhythm in a subject whilst he is waiting to respond, as well as during stimulation.

At the extremes: (1) Berger 1932, established that there was a marked reduction in the alpha rhythm during sleep. Loomis et al, 1935a, 1935b, 1936a, 1936b, studying all night records, observed the gradual reduction of the alpha rhythm during the drowsy phase of going to sleep, and called attention to a variety of 'new' wave forms and patterns appearing with the onset of sleep. Any disturbance of sleep caused a reversion to the lighter states and their corresponding patterns and, if the sleep was relatively light, alpha rhythm was observed for a short time. The wave forms of sleep seem to be in particular 12 to 15 per second spindle formations and random slow waves.

Epileptic stupor is accompanied by flattening of the record and complete disappearance of alpha rhythm, Berger, 1932, 1934. With oxygen lack, a similar record is obtained, Berger, 1934,

/Davis

Davis, Davis and Thompson, 1938. Breathing pure nitrogen, Gibbs et al., 1935, also caused depression, although these workers report a transitory increase in amplitude at the beginning of the experiment. Disturbance of consciousness then, are accompanied by a flattening of the record.

At the other end of the scale, Berger (1933), has reported that 'fright' abolishes the alpha rhythm for 15 to 20 seconds. Loomis et al. (1938a) and A.C. Williams (1940) state that embarrassment and apprehension practically suppress the alpha waves.

Lindsley (1951) states the case to which I am here subscribing, that the alhpa-rhythm appears to behave as an optimum state of relaxed consciousness. This he upholds with a wide variety of similar evidence and much from the clinical field.

I have discussed the extremes of the sleep-excitement scale; what of smaller differences of emotional tone? Travis and Hall (1938) report the change in the percentage time of alpha activity between two conditions of attention. First, the subjects were instructed to signal every after-image after a visual stimulus, and secondly, they were told not to pay attention to the after-images. A difference of 35% was found. This is, of course, a gross average, but it is indicative of my point of view. The authors conclude that they feel that certain psychological factors such as attention may be revealed in brain patterning and thus objectively studied. (Other evidence may be found in Table 1).

Jasper and Cruikshank (1937), studied the effect of visual

/stimulation

stimulation on the occipital alpha rhythm. After considering all the different ways of obtaining and measuring blocking, they conclude that the attention value, or arousal value, or organismic reaction value of a stimulus situation is important, rather than the modal or intensity attributes. Visual stimulation, they say, has the greatest preptency amongst the senses in control of "mental set" or "attention".

They suggest that the rhythmic attribute of the cortical activity is due to a pace-maker in the diencephalon, this being the primary centre of central integration of nervous processes involving the autonomic nervous system. Attention, they consider, is due to the degree of involvement of this centre.

As an example of the intimate relationship, it is known that the reaction time of thepupilliary reflex is of the same order as the alpha blocking time. Byrne's data give the figure at between 0.16 and 0.5 second. These are the same limits as for latency of blocking, as found by Jasper and Cruikshank. The same type of stimuli affect the two effects, and they are both intimately related to the diencephalon.

In conclusion, it is reasonable to assume that the alpha rhythm is correlated with attention. Most writers agree with Jasper and Cruikshank that a diencephalic pacemaker would be sufficient to account for its properties.

Chapter 6

Experiment One

To determine the locus of "attention" in relationship to "expectancy", an experiment was carried out which was closely modelled on Mowrer's experiment (see page 33).

The following points are to be noted. Firstly, that electroencephalographic recordings were taken simultaneously with the reaction time experiment; secondly, that the order of presentation was the same for each subject. Monopolar recordings were made from the occipital region and the central region with two channels of amplification and directly recorded on paper moving at 3.7 centimetres per second. Detail of the general experimental arrangements will be found in appendix 4 The group of 60 subjects was divided into 4. Different standard intervals were used with each group. Intervals of 12 seconds, 8 seconds, 4 seconds and 2 seconds were chosen.

The following order of presentation of stimuli was adopted. For the 12 second standard interval group, for the twenty-first stimulus occurred nine seconds after the twentieth. The twenty-seventh interval was of 15 seconds, the thirty-fifth of 6, the forty-first of 24, the forty-eighth of 12, the fifty-fifth of 3, the sixty-first of 18 and the sixty-eigth of 21 seconds. The remaining intervals between stimuli were of the standard length of 12 seconds. With the remaining groups (standard intervals of 8, 4 and 2 seconds) non-standard intervals were proportionally less

/and

and given in the same order. Each subject was instructed: to "press the key with the first two fingers of your right hand". The light (stimulus) will appear shortly afterwards. As soon as you see the light you must release the key and then press it again. I want you to respond as quickly as you can, as soon as you see the light. The light will go out when you release the key. Later on the light will come on again and, as soon as you see it, I want you to release the key and then press it again. Every time you see the light come on, I want you to release the key and then press it again. Do you understand?" The experiment proper was completed in the 68 intervals, often further stimuli were given after standard intervals without a break.

The experiment was conducted with the aim of examining the temporal course of the alpha activity in the E.E.G. during the standard intervals afforded by the experiment, and to compare it with that of expectancy inferred from the reaction time.

Records were cut across at the point of onset of the stimulus and placed below one another for comparison. In this experiment interest was centred on the occipital region.

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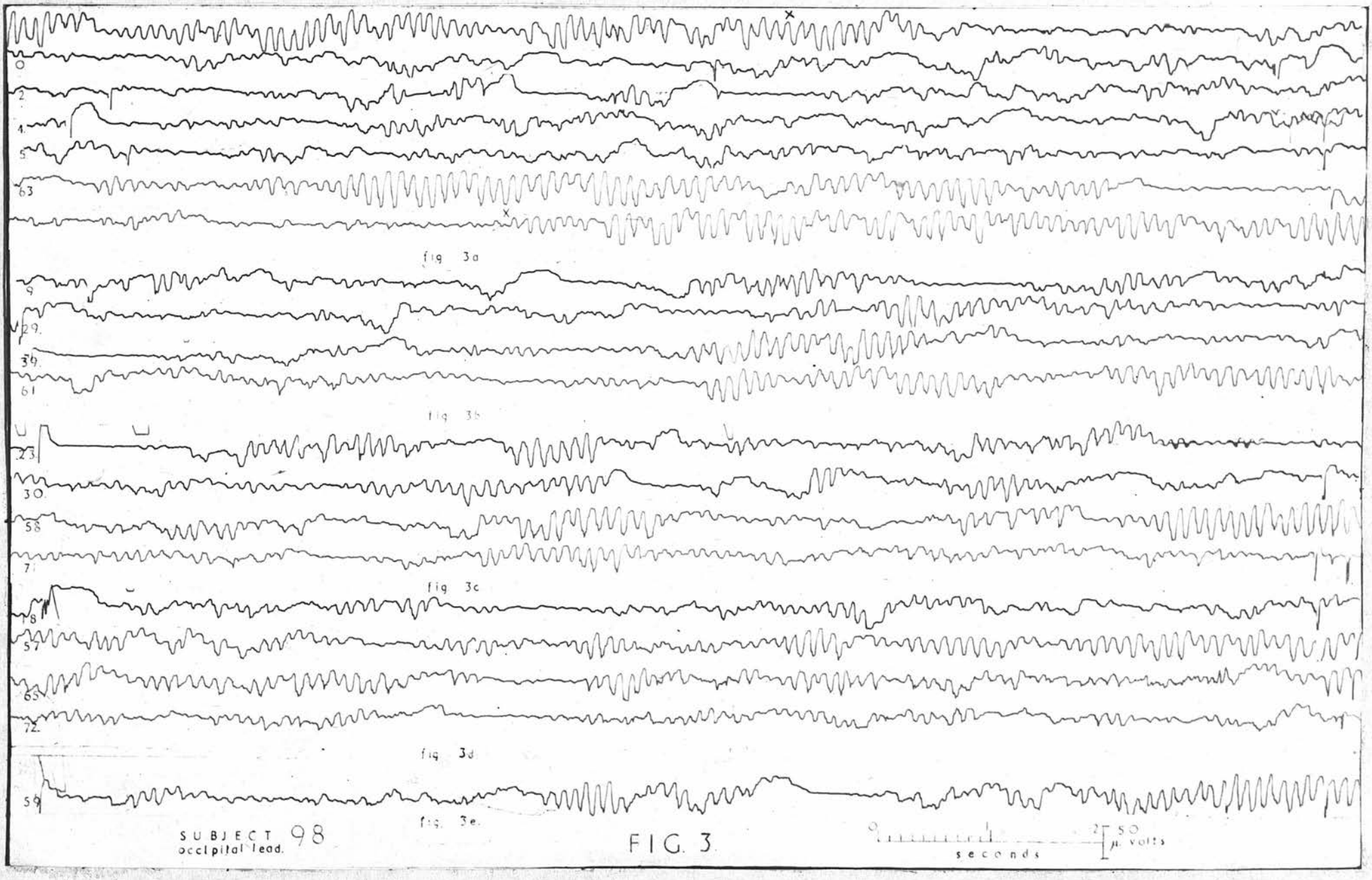
Results

The effect of a 12 second standard interval will be described first and the results compared with the shorter standard intervals later.

/Initially



SUBJECT 98
occipital lead.

FIG. 3

Initially very little alpha activity was observable and, in general, was not seen until the fourth or fifth interval with a 12 second standard interval. Its first appearance, usually as a short burst, occurred, in 60% of the records, in the first half of the interval, in 33%, in the second half, and 7% were indeterminate. The percentage time of the activity in the interval was seen to increase as the experiment progressed, until after perhaps 50 to 60 intervals, when a maximum was seen to be reached.

This growth or prolongation was not gradual or steady, but appeared to occur in "stages" with many regressions and repetitions. The final stage of maximum time of alpha activity was also labile and initially transient, but after about 70 reactions it was present in more than one-third of the intervals.

In Figure 3, the results are illustrated by some of the recordings from the occipital region of subject 98. Each line of tracing covers the period from the stimulus numbered on the left to the next stimulus. There are slight differences in the length which are due to variations in the speed of the paper.

In Figure 3a, the gross change between the general sequence of events during the twelve seconds preceding the first stimulus, to the 12 seconds following the last, is shown.

At x, in the first line, the instruction, "open your eyes", was given. Blocking of the alpha shythm took place approximately 1.1 seconds later.

The second line is continuous with the first, and the first

/stimulus

stimulus was given at the end of it. The next three lines were recorded after the second, fourth and fifth stimuli respectively, that is to say, early in the experiment, whilst the next line was taken from near the end, after 62 stimuli. The final line was taken in the period between fourteen seconds and twenty-six seconds after the last stimulus. At x, the instruction "close your eyes" was given. Before the first stimulus, the electrical activity is seen to be relatively random and fairly irregular, with some low amplitude 9 per second activity.

(After the first stimulus there is no appreciable difference and, for economy of space, this interval was excluded.) After the second stimulus it can be seen that the activity is still irregular, except for some indication that the 9 per second waves increase in amplitude in the first half of the interval. The same state of affairs was observed after the third stimulus (the record was not included). After the fourth stimulus, a pattern of alpha activity is observable which is again shown to some extent in the fifth interval. There is also a similarity in the slow activity with which we are not here concerned.

The record taken after the sixty-second stimulus is one of those showing a very high percentage time of high amplitude alpha activity and which occurred late in the experiment. This pattern is not common throughout the records and only occurs in the latter few reactions. After the instruction to close the eyes, 10 cycles per second activity is seen to have appeared immediately; this is

/augmented

augmented on the closing of the eyes about 0.8 second later. Three groups of records from the same subject, classified on the basis of occurrence of alpha activity, are shown in Figures 3b,c & d. Included in each group are the earliest occurrence of the pattern together with one of the latest, and two others to underline the common factors.

In Figure 3b, the alpha rhythm reaches full amplitude only after the half-way point. The difference in amplitude between the two halves of the interval is so striking that it requires no illumination.

In Figure 3c, the 'percentage time' of large amplitude alpha activity is biased towards the first half of the interval. In this subject the difference is relatively slight, but the classification is real, and for other subjects, as forceful as Figure 3b for subject 98. Interval 58 does not conform to this classification, and was included for that reason. The percentage time of large amplitude alpha activity is biased slightly in favour of the second half of the interval as a result of the presence of the burst of activity about one second before the stimulus was due. Apart from this, however, its pattern is, as the others, represented by Figure 3c.

In Figure 3d, is a group of records which show a series of bursts more or less over the whole interval. The record of the fifty-seventh interval was included in this group with the same reasoning as for the fifty-eighth interval in Figure 3c. In this

/group

group there is about the same percentage time of activity occurring in a series of bursts, in each semi-interval. This sort of pattern is common in some subjects but does not appear at all in others.

Figure 3e represents the occurrence, unique in this subject but common in others, of a short burst of activity in the centre of the interval. In this a node, or small time of lowered amplitude, occurs in the centre of the burst at approximately 6 seconds after the stimulus.

It will be seen from the figures that there is a verymarked tendency to show no alpha rhythm over the mid-point of the interval. I have, for convenience, described any lack of alpha at the centre point as a 'node", provided that alpha activity does occur in some part of the interval.

Illustrations of the way in which these patterns are related in succeeding intervals are given in Figures 4 to 8 in the appendix to this section (*appendix one*). Examples are taken 1)from the records of two subjects who show a moderate amount of alpha activity with the eyes closed and who show much the same final pattern (Figures 4a to b); 2) from the record of a predominantly "non-alpha type" (Figure 5a); 3) from the record which showed the fastest development and a high level of alpha activity very early in the experiment (Figure 6); 4) from the record of one of the above pair of subjects to illustrate the effect of a non-standard interval (Figure 5b); 5) from both the

/occipital

occipital and central leads to show the relationship between the patterns simultaneously appearing in the two leads.

(Detailed description of the figures is given in Appendix 1 also).

It is possible to define certain changes fairly clearly.

1) The effect of responding to equally spaced visual stimuli, was to increase the percentage time and amplitude of the alpha activity from zero or nearly so, to a value often higher than that in a state of relaxed restfulness with the eyes closed, despite the fact that during the whole of the experiment the subjects' eyes were open.

The greatest percentage time of alpha activity appeared in a single spindle, starting soon after the response, and blocking about one second before the next stimulus. This is always the last pattern to appear.

A slightly lower percentage time of alpha activity is observed if the interval, as above, shows a drop of amplitude or 'node'. This pattern, especially with the node at or very near to the mid-point of the interval, is, for many subjects, the most advanced pattern observed and, if not, it preceded the "whole cycle pattern" described above. This latter pattern may be thought of as the provision of a state of readiness twice as often as is required.

The pattern observed slightly earlier in the experiment can be thought of as being formed by dividing each of the major spindles of the second pattern, (as described in the last paragraph) into a

/series

series of short bursts. This was not observed in some subjects at all; in others it was fairly common.

One or other of the two spindles of the second pattern does not occur at all in many intervals, thus presenting two more patterns in which, again, there may be one or more bursts, but only in one half of the interval.

Lastly, the condition of no alpha activity must be mentioned as being the pattern of the first one or two intervals before any sensory organisation had been built up. The patterns are more or less individual for each subject but many common features are visible and, in particular, the fact of a "development" and gradual increment in the percentage time of alpha activity over the interval.

2) The development, and the changes following a non-standard interval, suggests that they are related to the standard interval and exist as a result of the repetitions of it and are, therefore, relevant to the temporal course of expectancy.

3) The central region, it is found, lags behind the occipital area where activity and "advanced" patterns are usually observed first.

Generally, however, the pattern of alpha activity in the two leads was the same, after the first few intervals.

The comparison of leads suggests an increased sensory (occipit lead) control of the motor area (central lead) as the development

/progresses

progresses, but not a dominance. This idea does not, however, account for the following two facts. Very occasionally, a non-standard interval, resulting in regression in the pattern in the occipital lead, leaves the central region unchanged, and, fairly frequently, a very small burst in the central recording precedes, by one or two intervals, the first appearance of a larger burst in both leads.

4) The pattern development depends upon the length of the standard interval.

The 12 second and the 8 second standard intervals, (figures 9 to 12) produced patterns as outlined. The 4 second standard interval (figures 13 to 16) produced a significantly lower percentage time of alpha activity. Patterns are developed, but over the experiment proper the final pattern was usually relatively primitive. Further trials, in some cases, provide patterns similar to those occurring in the experiments with longer standard intervals. There is a less pronounced node, though in many cases a phase change at the mid point is present. The occurrence of alpha activity is almost invariably biased towards the second half of the interval. The central lead follows the activity in the occipital lead in all but one subject, but the correspondence does not occur until later in the series than with the larger standard intervals.

With a standard interval of 2 seconds (figures 17 and 18) the results were similar for all subjects. A pattern was developed

/in

in which alpha rhythm occurred in the second half of the interval as a short burst of five to six waves. Occasionally, in the course of the experiment, alpha activity was seen to be present in the first half. It seemed to appear, however, as a continuation of a strong burst at the end of the previous interval, i.e. when blocking did not occur before the expected stimulus and then took longer than the reaction time.

There is a marked increase in beta (fast) activity in the two second standard intervals, and there are indications that this also is related to the interval.

5) The position of the first appearance of alpha rhythm seems to depend upon the rate of repetition of stimuli, and a temperamental factor in the individual subject. There are two main groups of subjects: those who first show alpha activity in the first half of the interval, and those who first show it in the second half. (60%, 40%, 20% and 0% showed alpha initially in the first halves of the 12 second, 8 second, 4 second and 2 second standard intervals respectively.) There is reason to consider that these groups represent variations in a temperamental factor. In the first group, when the stimulus and response are complete, tension drops, and mounts again towards the end of the half interval, staying up until the stimulus, as expected, occurs. This may be described as the "release group" at the appropriate frequency of response.

The second group showed blocking after the stimulus and

/response

response. The tension drops later in the interval, presumably when the effects of the stimulus and behavioural response have diminished. There is no question of not being prepared for the next stimulus, the alpha activity blocks in time for it. It is as if this group were unable to release quickly after the reaction, and may be described as "tense". The proportion of this group increased, with the increased rate of response of shorter standard intervals, to 100% with the two second standard interval. It is not known whether the efficiency of an operator in a similar situation is increased or decreased by falling into one or other of these groups. It looks, however, as if there will be an optimum frequency of response at which a subject is "just not" in the tense group. It seems most likely, that he would be able to maintain a high standard of efficiency for a longer time with lower frequencies ~~less~~ than ~~this~~ for higher rates of response, after a given amount of preliminary practice. The effect of repeating the standard interval is to increase the proportion of the interval in which the subject finds it possible to relax. Thus, though more practice will be necessary, it may be possible for some subjects to reach maximum efficiency even in the fastest repetitive task. If there is a limit to the rate of response under which relaxation may take place, it will be with a standard interval of very little less than two seconds.

The two subjects, extracts from whose records are shown in figures 9a and 9b, are comparable by this classification.

6) The number of intervals necessary before a particular pattern is reached, depends upon the pattern, the inverse of the length of the

/standard

standard intervals and the number of non-standard intervals, scattered throughout the series of equally spaced stimuli, and, of course, on the subject.

The patterns refer to the whole interval. The series is not at all times progressive. Apart from the regressions due to the non standard intervals, others occur which appear to be spontaneous.

7) Similar patterns from one subject are usually nearly identical in the position and duration of bursts of alpha rhythm. The duration and form of bursts are much the same as the bursts and spindles seen in the subjects' resting record.

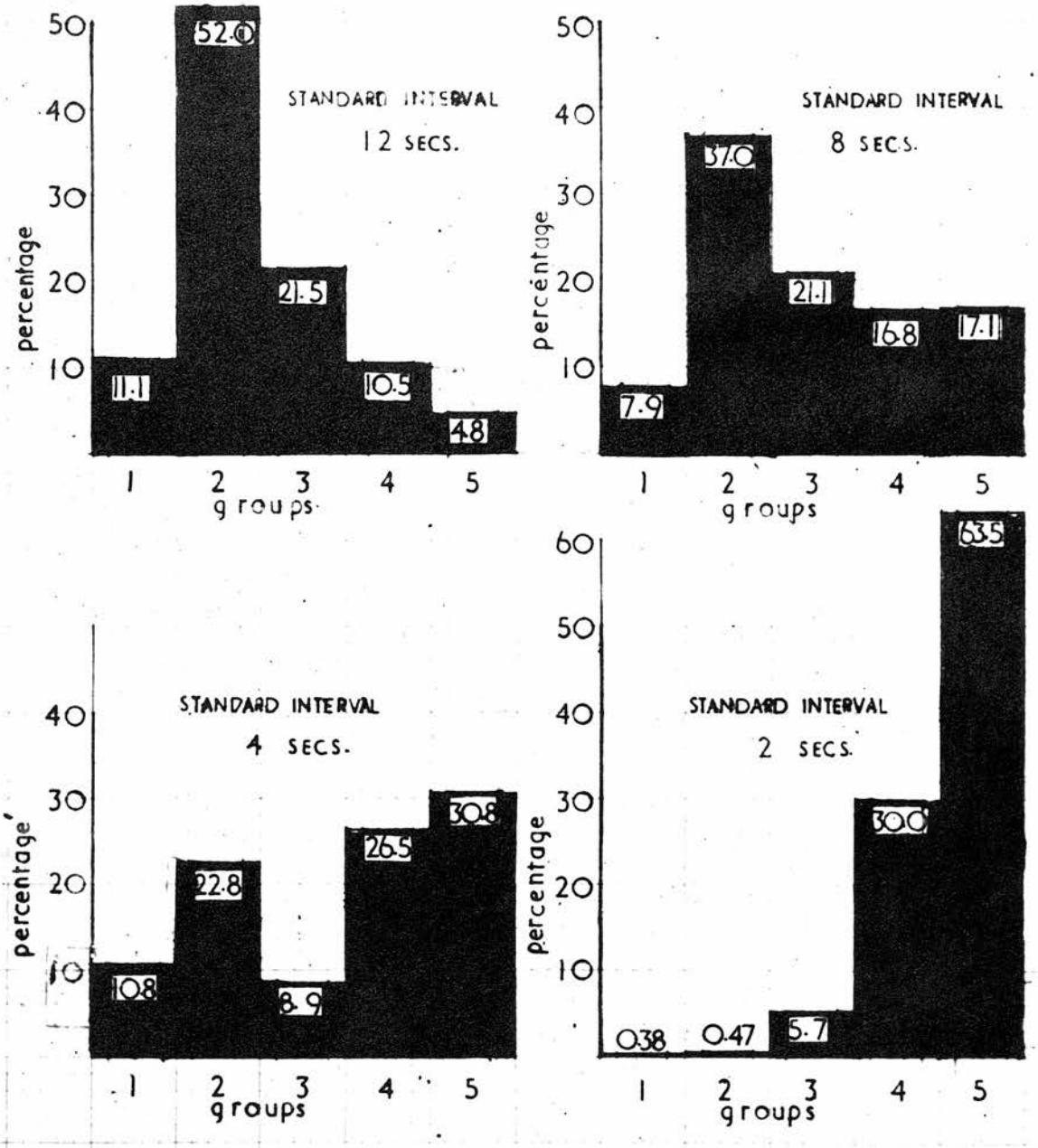
Contrasts are present which suggest that, in the earlier stages of the development, a burst will occur in either one position or to either side of this position. There is a marked tendency to show no alpha rhythm over the mid point of the interval.

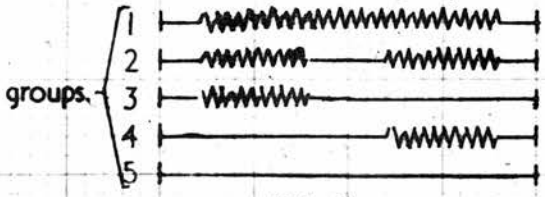
The amplitude of the alpha rhythm reaches its maximum before the final pattern is attained.

Similar final patterns shown by different subjects, are not necessarily the result of a similar series of stages leading to the final pattern.

8) The patterns in the occipital lead have been separated into five groups - Group I: Alpha activity which is unbroken at the centre of the interval. Group II: Alpha activity which occurs in both halves of the interval but which shows a drop at the centre of the interval. Group III: Alpha activity solely in the first half of the interval. Group IV: Alpha activity limited to the second half of the interval. Group V : No alpha activity at all.

/In





saw tooth represents alpha activity.

KEY
to groups in histogram.

PATTERNS OF ALPHA ACTIVITY IN THE STANDARD INTERVAL.

FIGURE 19

In Figure 19 are histograms of the percentages of the occurrence of intervals, showing the properties of one of the five groups ~~shown above~~ .for the various lengths of standard interval. The patterns examined were of the experiment proper, i.e. over the first 68 intervals. The various groups are schematically represented at the bottom of the figure and are referred to by numbers. The percentages for each group are marked.

Comparison of the percentages for various lengths of the standard interval shows that the faster the rate of stimuli, the greater the shift is from the left to the right of the histograms, i.e. from groups 1 and 2 to groups 4 and 5.

The proportion of responses with activity in either the first or second halves, i.e. the sum of groups three and four, remains approximately constant (e.g. 33%, 37.9%, 31.7% and 35%) and singly, the two groups bear an inverse relationship to one another.

In figure 20a, the percentages of the various groups of patterns are compared with the length of the standard interval. Groups two and five also show an inverse relationship. Group one is not clear. One possibility is that two opposite factors are operating; (1) the effect of decreasing the standard interval, which reduces the number of 'final' patterns; (2) a tendency of the mechanism to respond to the whole interval, the smaller it is.

Variations in Reaction Time

In figure 21, mean reaction times to the non-standard intervals and one standard interval are plotted. (These occurred

/as

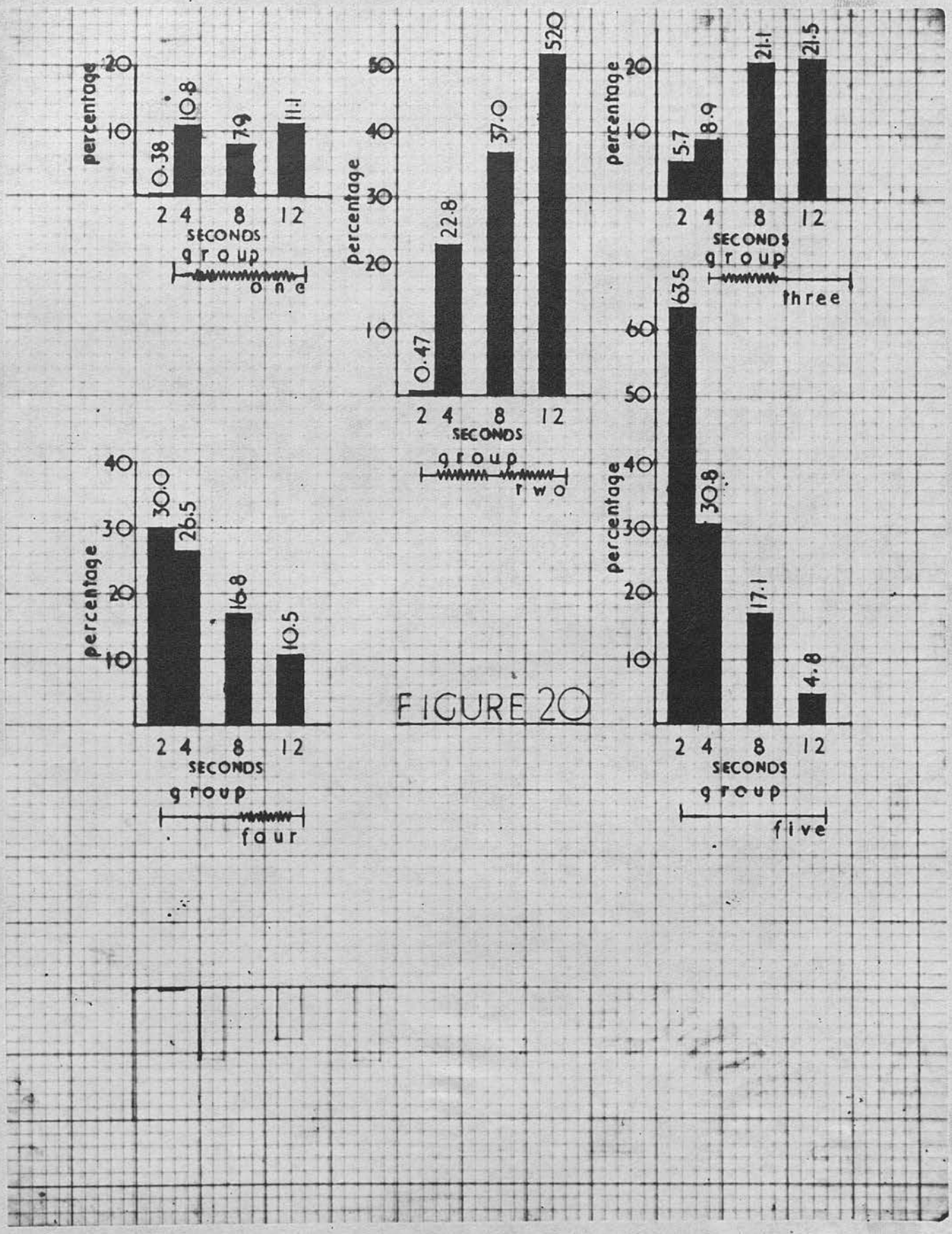

percentage
20
10
0·38
10·8
7·9
11·1
2 4 8 12
SECONDS
group
one
percentage
50
40
30
20
10
0·47
22·8
37·0
52·0
2 4 8 12
SECONDS
group
two
percentage
20
10
5·7
8·9
21·1
21·5
2 4 8 12
SECONDS
group
three
percentage
40
30
20
10
30·0
26·5
16·8
10·5
2 4 8 12
SECONDS
group
four
percentage
60
50
40
30
20
10
63·5
30·8
17·1
4·8
2 4 8 12
SECONDS
group
five

FIGURE 20

as the 21st, 27th, 35th, 41st, 48th, 53rd, 61st and 68th intervals and were respectively of $\frac{3s}{4}$, $\frac{5s}{4}$, $\frac{2s}{4}$, 2s, s, $\frac{s}{4}$, $\frac{6s}{4}$ and $\frac{7s}{4}$ where s is the length of the standard interval). Also plotted are Mowrer's results (as given in Figure 1).

The effect of the unexpected stimulus is to increase the time to respond proportionally to the deviation from the standard interval.

1) Like Mowrer's results, the time to respond after a non standard interval is increased, but there also appears to have been an interference with the process of organisation at the smallest fractions of s. In an experiment reported later in this paper in which conditions were similar, except that stimuli occurred after random intervals, the mean reaction time was .32 second. Perhaps it may be rationalised that the expectancy before $\frac{s}{2}$ is that the stimulus would not occur, whilst after $\frac{s}{2}$, and before s, the expectancy would be of the stimulus occurring. Interference due to any after effect from the previous stimulus and response may also be expected.

2) The stimuli occurring after 2s show that, on the average, when s = 12 or 8, and in some subjects 4 secs, the subject was more prepared for the stimulus than at moments slightly earlier.

3) The disruption is less at intervals greater than s than in those less than s.

4) With 12 and 8 sec. standard intervals, the reaction time to $\frac{s}{2}$ is less than would be predicted by a smooth curve through $\frac{s}{4}$

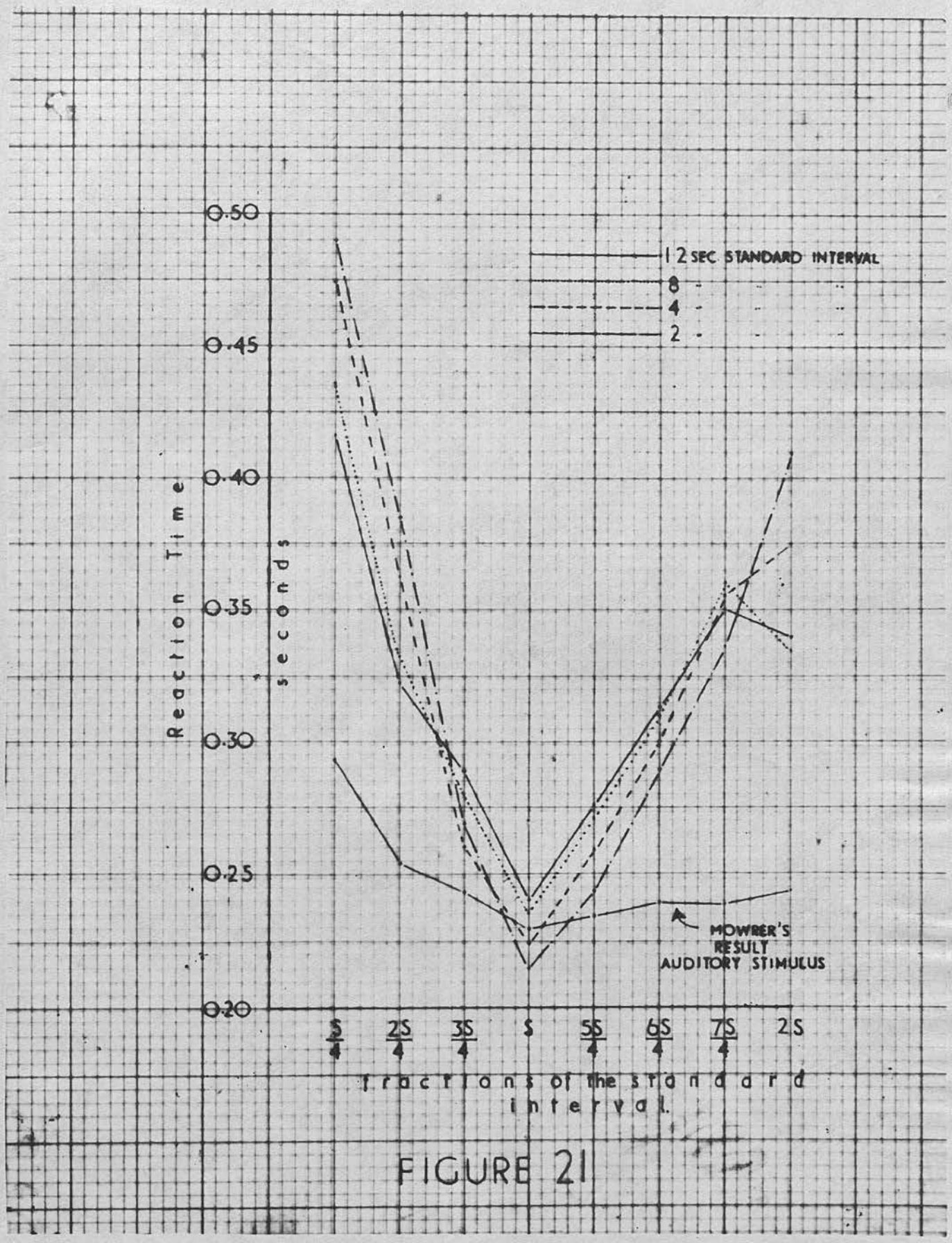

0.50
0.45
0.40
0.35
0.30
0.25
0.20
Reaction Time
seconds
1 2 SEC STANDARD INTERVAL
8
4
2
MOWRER'S
RESULT
AUDITORY STIMULUS
S/4
2S/4
3S/4
S
5S/4
6S/4
7S/4
2S
fractions of the standard
interval.

FIGURE 21

$\frac{s}{4}$, $\frac{3s}{4}$ and s.

Discussion

If Mowrer's exposition is accepted, then we should expect from the reaction time results, a pattern showing alpha activity in the first part of the interval which decreases as the interval proceeds. Such a pattern does occur but not consistently, and it isusually replaced by other patterns as the expectancy is developed over further trials.

Figures 19 and 20 show that the effect of shortening the standard interval is to change the pattern, from predominantly alpha activity in both halves of the 12 second interval to predominantly no activity at all in the two second interval. When present, it is found entirely in the second half of the shortest standard interval. The changes appear to be smooth and to follow some simple relationship.

The effect on the reaction time of the change of length of the standard interval does not follow a proportional relationship to the standard interval in the manner of the alpha activity.

It may be argued that attention is bound to affect the reaction time, it must therefore, be the state of attention at the onset of the stimulus. The relationship of this state of attention with the preceeding seconds is probably immaterial.

/The

The patterns are, with very few exceptions, related to the standard intervals so that there was usually very little alpha activity at the actual onset of the stimulus. In the non standard intervals, it depends upon which of the patterns is developing and at what point in this pattern the stimulus arrives, whether or not alpha activity is present. From this we may predict that the shape of the curves, figure 21, may be altered, at least to a certain extent, by changing the order of the non-standard intervals during a repetition of the experiment with a balanced random order of the non-standard intervals over all subjects.

In conclusion the temporal course of the alpha rhythm is not constant but variable and does not conform to the pattern observed from the reaction times.

Chapter 7

Experiment Two

It may be argued that the previous results are due to the high motivation or other aspects, possibly not defined, of the reaction time situation.

A further experiment was carried out to examine the control of the alpha rhythm by an organisation built up from regular features of the experiment.

The motivation was kept as low as possible. There was, for instance, no instruction to respond as fast as possible. The meaningfulness of the process to the subject was also kept to a minimum.

The experiment consisted of a series of instructions, given regularly every five seconds, to open and close the eyes; this, in a dim, but not dark, sound-proof room.

A microphone and amplifier were connected to a loud-speaker in the sound-proof room and to one of the recording pens. The other pen recorded the activity of the left occipital area of the brain.

This experiment was performed as the last act in the experimental session with each subject who took part in two of the experiments to be reported later in this paper. These later experiments did not include regularly occurring stimuli.

The instructions, "open your eyes", followed five seconds later by, "close your eyes", etc. were given as the pointer of a large stop-clock reached successive five second marks. The accuracy of

/each

each interval was not high and the intervals varied occasionally by as much as 0.5 second. Such a degree of accuracy was found to be sufficient to show the effects. Records were cut after each ten seconds, at the instruction to "close" the eyes, and displayed beneath one another as in the last experiment. Each line will be called a cycle, which is divided into a first interval with the eyes closed, and a second interval with the eyes open.

The first line is the record of five seconds with the eyes closed before the experiment, and the five seconds following the first intruction to open the eyes. Thereafter, ten cycles were recorded. The eleventh cycle consisted of five seconds with the eyes closed, followed by ten seconds with the eyes open, i.e., twenty-two intervals of five seconds after the first instruction, an instruction to "close" was delayed until ten seconds had elapsed instead of five. This cycle was of fifteen seconds instead of the usual ten. It is displayed at the end of the series which was completed by three more cycles of ten seconds. The fifteenth cycle was of fifteen seconds. The first interval of ten seconds with the eyes closed, and the second interval with the eyes open, lasted five seconds. The instruction, "close" was then given and the recording continued for a short time with no further instructions. The ten seconds of record immediately following the last instruction to close the eyes is included and referred to as the sixteenth cycle. The

/results

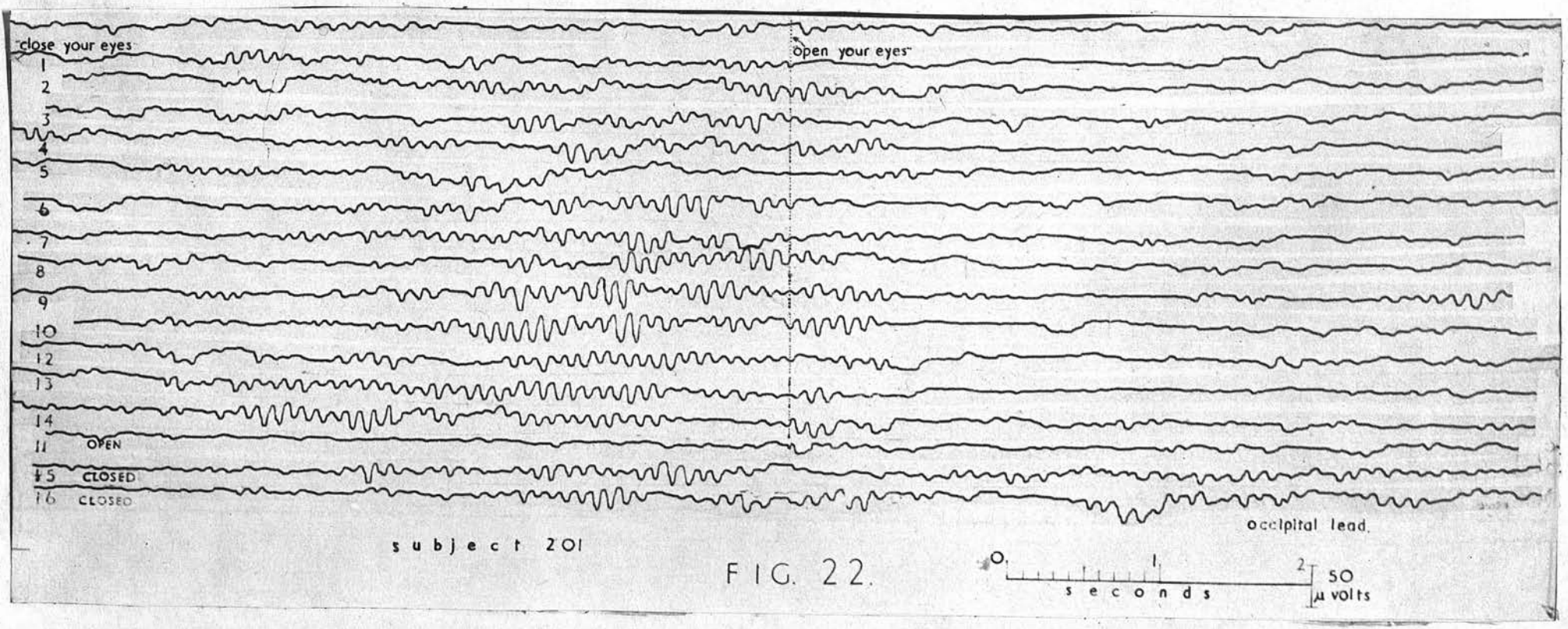

close your eyes
open your eyes
1
2
3
4
5
6
7
8
9
10
12
13
14
11 OPEN
15 CLOSED
16 CLOSED
occipital lead.
subject 201
0
1
2
seconds
50
μ volts

FIG. 22.

results are illustrated by figure 22 which is the record of subject 201. Alpha activity occurs in the first interval, blocks after the instruction to open, and returns only in small ripples in the second interval. The amplitude is seen to increase, particularly in the ninth cycle. The balance of activity is definitely towards the second half of the first interval until cycle thirteen when it spreads in the familiar spindle of the final pattern of the last experiment, over the full interval, blocking before the expected stimulus. This is repeated in the first interval of cycle fourteen, though there is some evidence of a node. Blocking before the end of the first interval is seen first in cycle four. After the instruction, a series of waves appear as though the result of the instruction.

The general effect of the regularly given instructions was to increase the amplitude and percentage time of alpha activity whilst the eyes were closed, (compared with the first five seconds of the first line of record, i.e. before the first instruction to open the eyes had been given.) It is to be noted that, though the second half of the first intervals in each cycle shows most alpha activity, it is seen initially in the first half of the first interval in cycle one. A change to a different pattern occurs in the third to fifth cycles of most subjects.

The first five seconds of cycle eleven are not shown. The ten seconds with the eyes open have been placed at the end of the series. At the centre of this interval, i.e. after five seconds,

/there

there is a short burst of alpha activity. This is the moment when the instruction to close is expected. Throughout the remainder of the interval, some low amplitude alpha ripplies can be seen, but they do not show any more clearly than in other intervals, late in the experiment, with the eyes open. With the eyes closed for ten seconds in the first interval of cycle fifteen, a drop in the alpha activity is seen at the expected time of opening. In the remainder of the interval, alpha activity of a slightly lower amplitude is present, reducing once more in amplitude before the end of the interval. The second interval (of five seconds), of cycle fifteen, is not shown. In cycle sixteen (the first ten seconds following the experiment) the pattern of the first five seconds is more like the earlier cycles of the series, possibly due to the interference of the longer interval in cycle fifteen. A small node is seen at the mid point followed by a large amplitude burst, blocking for a short time, and then an irregular series of fairly large amplitude waves which diminish before the end of the ten seconds. The developed sensory organisation is seen to control the alpha rhythm. The similarity to the previous experiment is striking, and the increase of percentage time and aplitude, surprising.

The individual variations are illustrated by figures 23 to 26 in Appendix 2, ~~to this section~~ where detailed descriptions of the records are given.

The examples in Appendix 2 were not entirely randomly chosen,

/but

but they convey the correct general impression of the effect of regularly opening and closing of the eyes to instructions. In general, the result of the procedure as described, is to increase the percentage time and amplitude of the alpha activity with the eyes closed, as compared with the record with eyes closed before the experiment. The most common pattern in the later cycles is of a spindle of activity starting about one second after the instruction to close the eyes, and blocking about the same time before the instruction to open the eyes. The development seems to be more straightforward than in the previous experiment and with fewer regressions.

Four stages are clear in all records. First, the activity occurs in a manner and pattern similar to that before the experiment. This lasts for two or three cycles. The second stage in the waves seems to show that the sensory organisation is becoming adapted to the cycle. The bursts appear symmetrically in the first interval or blocks before the instruction to open the eyes, or in some way, changes from the rather more irregular patterning of the first cycles. The third stage is represented by a diminution of amplitude, duration or both, together with, very often, a change in position of the dominant alpha activity, usually to an earlier position in the first interval. This stage may be thought of as a reorganising phase. The fourth stage is the regrowth of the alpha spindle and its amplitude to the final pattern.

/Other

Other changes which occur are ~~divided in some way amongst the subject, and are~~ combined differently for different subjects for reasons which are not clear.

One factor affecting the distribution of these different ways of behaving to the same situation is, undoubtedly, the 'normal', resting state of the alpha rhythm. This, however, is not the most important. Attempted estimation of its relationship to the situation has led to the conclusion that the source of the alpha rhythm and the factors regulating it under resting conditions, have only a limited influence on the changes under conditions of even the most elementary activity. Its amplitude, regularity frequency and pattern are determined by one set of factors in the resting state. Under conditions of stimulation, other factors, only at times related to the first set, also act to modify and change the alpha rhythm. This conclusion recalls that of Darrow et al, 1946, that in the resting state there may be a subcortical preponderance over the effects of the cortex, and that the cortical (stimulation) and subcortical (resting) influences on the alpha rhythm mutually oppose one another.

In the second interval of each cycle, the most common pattern is a burst of about six waves starting at the instruction to open the eyes, or persisting from the previous interval. These are followed by almost complete blocking for the remainder of the interval in eighty-six per cent of the intervals. Some low amplitude activity may be seen at alpha frequency in some parts of

/the

the second intervals of the later cycles. This, however, is not the only pattern. In ten per cent of the subjects, the alpha activity in the second interval increases in duration, amplitude and regularity until, sometimes, the difference between the first and second intervals is then very small. In this pattern, the subjects also showed the train of waves starting with the instruction to open the eyes.

Not all the subjects responded by a series of waves to the instruction; it may be accompanied by immediate blocking. This may be described as auditory stimulation eliciting an unusual amount of attention. The effect diminishes as the experiment progresses.

When the subject is left with his eyes open longer than he expects, the most usual response is a repetition of whatever pattern was observed in the first five seconds. Fifteen per cent showed some increase in alpha activity of which about one third showed it to a fair amplitude, i.e. at least twenty five micro volts, in the second five seconds of the interval, following blocking in the first five seconds.

In cycle fifteen, when the instruction to open the eyes was not given after five seconds, ten per cent blocked for one second, starting just less than five seconds after the instruction to close the eyes, at the beginning of the cycle. The remainder, after having blocked about the same time as the above group, showed a spindle of alpha activity which started just after the fifth second of the cycle. The duration of this spindle se

to depend upon the pattern developed in previous cycles by the subject, for most often the pattern of this second five seconds is a repetition of the pattern in the first intervals of the previous few cycles.

In most subjects, the alpha rhythm first appears three-quarters of a second after the instruction to close the eyes. The exceptions are those subjects who show definite signs of alpha rhythm with the eyes open. These subjects, as for instance subject 193, figure twenty-three and subject 213, figure 24a, show alpha rhythm which starts at the instruction to open the eyes, or slightly before. The duration may be as much as two seconds or as little as a few waves. This part of the interval does not show the consistency as that following the instruction to open the eyes. After a number of cycles, activity, parallel to the instruction to close the eyes, disappears; eight to twelve are usually sufficient c.f. figure 24a.

I have found it useful to think of two types of subject. There are those who react to the experiment as if the interval with the eyes open is a temporary break in the time with the eyes closed, and the opposite group who react as if the eyes being closed were a break in the natural state with the eyes open. The first group shows alpha rhythm, in the period with the eyes open, which gradually increases, and the second by a marked increment in the alpha activity in the first interval. No specific visual stimulation occurred when the eyes were open and the first group

/would

would be reinforced as the experiment progresses. The second group could relax more and more with the eyes closed as the experiment progressed, and when occasionally the experiment was continued for a larger number, up to 50 cycles, it was always possible to detect intervals when the eyes were open showing alpha activity at a moderate amplitude. Popov has reported, (1951) that with all subjects in a completely dark room it takes very few, of the order of ten, cycles for alpha activity not to block with the eyes open, and that it shows properties of an extinguished conditioned response on retest.

The description of the above groups canbe paraphrased as follows: Non-specific visual stimulation holds a greater prepotency to action for the second group than for the first who show alpha activity when the eyes are open from the first few cycles. These may correspond to the tense and relaxed groups of the previous experiment. They are also reminiscent of the classification of image type made by Walter, 1950.

In conclusion, the alpha rhythm may be controlled by a sensory organisation built up as a result of regular, repeated instructions to open and close the eyes, and a further result is that there is an increase in the amplitude of this activity at certain times between the instructions.

This experiment therefore, substantiates, in relationship to the particular conditions of test, the results of experiment one.

Chapter 8

The Mechanisms of 'Set'

Two experiments have been described which were designed to detect a relationship between attention and sensory organisation. Both experiments showed regular features of the electroencephalograph. Evidence was presented showing that the features were intimately related to attention, and the control of them to sensory organisation.

Attention and sensory organisation are very often difficult to separate. Attention is a necessary 'aid' to the formation of a sensory organisation and, in so far as it is thus bound up with the sensory organisation, the organisation will appear to, and possible actually does, control attention. One of the effects of the development of a sensory organisation is that the attention drops, particularly when the next stimulus is not expected.

At times, attention and sensory organisation are oppositely orientated or independent. For instance, attention becomes mobilised when a stimulus appears unexpectedly. If the rate of change of attention is high, a startle response is said to have occurred. Increasing the rate of repetition of the stimulus alters the pattern of attention during the intervals between stimuli. It does not, however, appear to change appreciably the acquisition of effects of a sensory organisation within the limits of interval length with which I have been working.

Sensory organisation is devoted to the adaptation of the

/organism

organism to ingoing stimuli, attention to the occasions when such adaptation is at variance with the ingoing stimuli. There is some justification for saying that this variance represents irritation to the organism. The effect of the attention appears then to be twofold in the removal of the irritation, first, as a priming factor to remove the source of irritation; secondly, if that is impossible, as an aid to a new adaptation.

It is reasonable to conclude, therefore, that 'attention' and 'expectancy' are separable. We can also show a difference of motor organisation, ('intention') from 'expectancy' (ablation experiments, etc.). Are 'intention' and 'attention' equated, they might well be; no proof can be found which will decisively separate them, since motor organisation plays a part in all behavioural responses. It is suggested that the relationship between them should be very similar to that between attention and sensory organisation.

In spite of the lack of proof, I think there is good reason to separate three mechanisms theoretically as: Sensory organisation (subjectively expectancy); Attention (subjectively tension); and Motor organisation. It has been pointed out that 'intention' is motor organisation plus motivation. The motivational parts of the concept can most certainly be called 'attention'. In making this distinction it must be pointed out that there is no reason why these mechanisms should be considered as existing only to provide the facilities of 'set' to the animal and human. On

/the

the contrary, it is considered that these factors are merely part of the central adjustment mechanism and are occasioned as a function of the environment, or as in this case, of the experimental method. In making this point the facts and theories of learning must be taken into account.

In the earlier discussion of the place of 'set' in the learning theories, it was concluded that the most reasonable position in the discussion of constructs of learning is that which admits both contiguity and the law of effect to be important factors. In view of this and of the evidence for sensory organisation, the position to be taken is most similar to that taken by Woodworth, (1947), who emphasises both 'the perceptual nature of learning' and the 'principle of reinforcement'. His view is that reinforcement is responsible for the hypothetical learning change in conditioning, but that this change is not to be thought of as strengthening the CS-CR connection. Woodworth employs a concept of expectancy and states that it is the expectancy that is reinforced. This is similar to the position adopted by Lewin, (1942), who in criticising the associationist concepts of Koffka and Köhler, suggests that an association is not the force that can produce responses, "It must only be thought of as providing for the organisation of cognitions which must in turn be energised by the motivational systems of the individual before action". It is interesting here to compare Hull's concept of habit strength, Hull, (1943). The habit strength alone

/cannot

cannot produce a response but must be combined with the coexisting drive state in order to do so.

If this position is accepted, then it follows immediately that motor organisation and motivation can be separated. In a complex learning situation, for instance, a problem box, the animal having learned the task of, say, moving a lever to open a door to the reward, is liable to move the lever with one of many different movements of different limbs. Each of these movements will include a high degree of co-ordination between various muscle groups including postural reflexes, etc. which have been learned prior to the experiment, and exist as a series of motor organisations. The sensory organisation of the relationship between the lever and the door and reward will not vary, and the motivation can be made very nearly similar in each of two or more cases when a completely different movement, or even limb, is used to perform the action of pressing the lever. The motor organisation is, therefore, not necessarily specific to a specific motivation in any one situation, and the two aspects are separable, as everyday experience would seem to predict.

Of the remaining four concepts of the temporary schema, I find they can all be interpreted as combinations of the three mechanisms which I have suggested above. 'Attitude' was shown by Hebb to be a complex of expectancies (conceptual cycles). Often attitude is given motor connotations - attitude to react in a certain way, e.g. transfer of training - in which case we

/are

are talking about motor organisation, or it may be viewed as a drive to do something, in which case we can talk of attention.

Transfer of training is also often used with reference to familiarity with the stimulus pattern, in which case we have expectancy. Previously I referred to it as 'habit'.

The temporary persistence of a sensory organisation, or a 'hypothesis', becomes a conceptual cycle, represented in Hebb's terminology, by any one of the letters of the sequence a-b-c-a-... or A-B-C-D-A-B- ...., which refer to an expectancy and an 'attitude' respectively.

'Expectation' is essentially a sensory attitude based on the arousal of previously established 'expectancies' (cell assemblies), possibly verbally.

The Nature of the Mechanisms

It may not be possible to explain psychological constructs physically, but they must have physiological and, if possible, anatomical reality, i.e. they must be physically possible.

I shall attempt in the following to indicate that the mechanisms are to some extent physically probable.

Stimulation of the cortical grey matter invariably produces, whatever the nature of the stimulus, a local activity which tends to be spread in one of two ways: (a) propagation which tends to be corticofugal and moves very slowly from the excited point within the cortical feltwork. This activity which is carried through numerous synapses travels with a speed of about 10 milli-

/metres

metres per second (McCulloch, 1949). (Adrian, 1934 gave the figure of 40 millimetres per second). (b) An activity tending to follow the course of the projection axons, leaving the stimulated regions, and having a great velocity towards other points on the cortex, which always seem to be the same (McCulloch, 1949).

Changes in the intensity and duration of the stimulus principally affect the after discharge and the transmission at a distance (Dow, 1949). The separability of these two mechanism seems to offer a suggestion for the basis of sensory association and organisation on the one hand, and sensory motor connection on the other.

Sensory Organisation, Expectancy

Expectancy is the effect of a sensory organisation which is referred to the subject, but is objectively studied in the changes of his behaviour in successive trials of the task.

Basically, expectancy with its integration as expectation, and more generally as attitude, is not necessarily formed according to the law of effect. A further proof of this is available from the work of Popov (1950). He recorded the spontaneous waves from the brains of animals and man under conditions of rest, and when a light was flashed at intervals (of one second and two seconds), the subject was behaviourally passive, but, after between two and five repetitions of the light, the pattern of waves became sychronous with the light.

It appears to be the same mechanism in operation when the

/light

light is flashing at any speed. Exactly comparable effects can be shown with frequencies as high as ten or eleven per second. At greater frequencies lower harmonics are responded to. Most important is the fact that the effect of Cyclochronie, as Popov calls it, occurs at least once after the stimulation has been terminated, at a point, corresponding to one standard interval after the last stimulation. It is suggested that it is this aspect of the mechanism of sensory organisation which is occurring in Mowrer's experiments on expectancy.

The description of sensory organisation given by Hebb, 1949, is entirely in keeping with my concept and the above facts. I cannot therefore, do better than to refer to his description.

Attention

Attention is secondary motivation. It seems to occur as a result of previous contiguity of motivation and certain stimuli. It is also intimately related to the chemical - hormonal state of the organism. The two aspects are separable.

(1) A facilitation via thalamo-cortical neural connections, of probably all cell assembly activities of other than those of the minimum duration, i.e. to which 'attention is paid'. It is well known that there is a minimum potential level necessary to induce a trans-synaptical conduction. This might be attained by duplication of fibres or by increment in the size of single afferents in relational positions (synaptic knobs) as Hebb postulates. In the

/problems

problems we are dealing with, the number of trials , does not appear sufficient to cause the generation of 'knobs', and we are faced with the necessity of suggesting an alternative mechanism for the maintenance of certain cell assemblies, which the organism facilitates into longer temporal existence. Impulses from the lower centres in the diencephalon might well serve to accomplish this state of affairs.

The existance of thalamo-coritcal circuits has been recognised since the last century. Dusser de Barenne and McCulloch (1938) established that there exists between the sensory nuclei of the thalamus, direct functional inter-relationships from each sub-division of the sensory cortex to, and only to, the corresponding sensory thalamic nucleus and vice versa. They infer from this observation that this closed chain of neurones should exhibit reverberating activity, and that once an excitation is initiated in part of the circuit, it should be propagated along the neurones connecting the sensory cortex and the thalamus, and back again. Recently this concept of cortico-thalamic reverberation has been much discussed, and used extensively in the interpretation of different rhythms. Chang (1950) analyses the periodic after-discharge to a single stimulus applied to the optic nerve, on the assumption that the waves are repetitive discharges of the circuits between the cortex and thalamus, and thalamus and cortex. He believes that an afferent volley from the thalamus, after arriving at the sensory cortex, will return to the thalamic nucleus, from which the impulses will again ascend to the cortex to start another cycle of activity along

/the

the same neuronal circuit, and this is repeated a number of times. The maximal evoked primary response can be obtained only at a focal point in the cortical region concerned. The repetitive discharges, consequent to cortical excitation by an afferent volley, are present only where the primary responses can be recorded (Chang, 1950). These secondary repetitive responses are, however, not localised and never seem to have a focal point on the cortex, where a response of maximal magnitude can be obtained. They do not appear beyond the boundary of the cortical area which is specially receptive to the impulses of that particular sensory modality, and they usually number four or five in direct recording. Cajal (1903) first suggested that the functional significance of cortico-thalamic circuits is as a mechanism for sensory attention. This latter he defines as the capacity of limiting our conscious activity to a particular region of sensory fields, cutaneous, visual or auditory.

The secondary discharges outlast the original stimulus by several thousand times, and according to Chang (1950), they constitute an "elementary physiological substratum for the formation and persistence of a mental impression aroused by the sensory stimulus" (cf. Hebb, 1949). There is no explicit bodily activity associated with the reverberatory discharge.

The facilitation of sensory organisations would be delicate and transient and under severe conditions we would expect it to break down. Examples of such conditions are frustration, or neurotic anxiety, in which cases we have regression to 'childish' behaviour, to well-established mechanisms learned earlier in life.

/This

This condition brings me to the second aspect of secondary motivation.

(2) The 'emergency response' which is probably in large part a humoural transmission; the presence in the blood bathing the brain of various chemicals which act as "to whom it may concern" messages (Wiener 1950). § Evidence that the cortical cells in vivo bear no resemblance to the classical telephone switchboard concept, may support this contention. Harrison, 1906-7, first reported that nerve cells are amoeboid in tissue culture. Levi, 1925-6, studied individual cells by microdisection of tissue cultures, and found that a nerve cell touched by a needle point will sometimes throw out processes by amboeboid movement. Tissue culture conditions are abnormal and artifacts are common, but Speidel, 1933, 1940, observed nerve fibres growing into the living tadpole tail. The ends of the fibres, like those in the tissue culture, were actively amoeboid. Carey and others, 1945, studying the motor end-plate, report that it too is amoeboid. Gerrard, 1949, says, "One thing, overwhelmingly impressive..... is the complete.... structural fluidity of an adult neurone under normal conditions, and its extensive disruption and reconstruction under very slight pathological conditions.

> In each of our brains at this moment..... each (neurone) is giving out pseudopods, retracting its fibres, moving forward and back, swelling and shrinking and moving from side to side".

Finally, it is only necessary to point out that, under the effect of certain chemicals, such activity in many kinds of cells can be accelerated or reduced.

/Supporting

Supporting evidence from the examination of the electroencephalo-graph and blood composition has been mentioned at the beginning of this section. The effect is very well known with all tissues. In particular, Speidel, 1940, studied the effects of metrazol on the preparation referred to above, and showed that active contraction of the fibres occurred and extension followed later, after an interval. If, under frustration, etc., a chemical is produced such that the cortical cells are reduced in their activity (reduction in amount of blood by constriction of the capilliaries might be sufficient) it is more likely that primitive, well-established pathways will remain active after the newer overlay is inoperative, and so we get regression characteristics.

This hypothetical explanation is intended as an example of the way in which the facts fit the behavioural details. 'To whom it may concern', humorally transmitted messages are common throughout the body, and facilitation of the development of a sensory organisation via neural connections will include repeated association . Attention and sensory organisation should, therefore, remain associated. The process of creating a sensory organisation will include circular loops, such that the organisation, facilitated from the lower centres, will affect the lower centres, and to this extent control their activity. It is because attention facilitates the development of the sensory organisation that the whole system becomes linked and a sensory organisation can control attention. On the other hand, if an 'unexpected' stimulus

/appears

appears, i.e. when the attention is not high, there is xx a very sharp rise in attention resulting in a discharge of the 'humoural message'. In Ashby's terminology, a step function has changed and we have the familiar 'startle response'. The effect in the electroencephalogram is that the alpha rhythm is blocked in the first case, just before an expected stimulus, and in the second, just after an unexpected stimulus. This idea is a corollary of Hebb's theory. The 'humoural message' is also produced in Hebb's terminology by a startle, i.e. an unexpected stimulus. To refer to the discussion of the humoural transmission, a frustration is exactly this.

Lindsley (1950), presents an 'activation theory' of emotion in which he states that emotion and deep sleep are extremes of the same dimension. The optimum centre point of this continuum is relaxed wakefulness in which the alpha rhythm is dominant. It appears from Walter (1950b) that emotion of a disruptive order is accompanied by four per second waves, but Lindsley makes no mention of this fact. However, even though it is not necessarily true to say that emotion is completely shown by the 'activation pattern' (blocking of the alpha rhythm and fast low voltage activity), it seems generally agreed that this pattern indicates emotion either organised in which case we have tension, or disorganised as excitement, irritability, and more or less gross forms of breakdown.

Motor Organisation

Motor organisation is considered to be homologous with sensory

/organisation

organisation in terms of mechanism. A transient, labile, integration of elements in the prefrontal cortex built up in a few trials by contiguity. The same pattern of theory may be built up for this activity and its complications (c.f. Morgan's seratim functions of symbolic processes) as Hebb has done for the case of visual perception. The concept of motor organisation may lead to confusion with skill unless it is realised that the difference is probably only one of degree. An alternative name may be pre-motor organisation since the observation may be made that behavioural evidence of motor organisation must always involve motivational aspects, i.e. there must be a power supply.

PART 3. SECTION THREE

CHAPTER 9

EXPERIMENT THREE.

In the previous pages suggestions about the nature of the mechanisms intervening between the 'stimulus and response', and showing behavioural effects referred to as set, have been made. The next stage of the programme is to ascertain how the mechanism of sensory organisation may be shown to operate in the reaction time situation.

In the experiment to be described the aim was to examine the ancipatory response to an expected stimulus. The method to be used is known in other, but sometimes comparable, fields of study as the 'black box' technique.

This involves the examination of the whole or large sections of the machine, and comparing the output with a known input. We have little alternative but use this technique in studying behaviour, and the stimulus-response approach of Hull and his associates is an example of this technique, applied, as Hull says, "macroscopically". The anatomical divisions of the cortex are unfortunately not related to the functional pathways as Penfield and Lashley, preëminantly, have shown. Nevertheless, at a very general level of description such as that of the electroencephalograph, various gross areas may be delineated. Widely separated areas of the cortex show different patterns and it was decided to record from the occipital, parietal and central regions, the response of the cortex to a recognisable input

acting as the stimulus in a reaction time experiment.

An experiment, similar in many ways, has been performed by Livanov and Poliakov, the important difference being that the "conditioned" stimulus (preparatory signal) was flashing and the "unconditioned" stimulus was an electric shock to the paw of a rabbit.

Livanov and Poliakov (1945) report that a conditioned reflex to rhythmic stimuli can be followed in the change of electrical pattern in the cortex of an unanaesthetized rabbit. During the generalisation phase of the conditioning, activity at the frequency of the conditioned stimulus spreads from the reception area to nearly all areas, later it is only found in the effector field corresponding to the unconditioned response, at this stage the behavioural conditioned reflex appears. They say that all the features of Pavlovian conditioning can be so examined.

Popov (1948a, 1949) shows that the assertions of Livanov and Poliakov are well founded.

Popov (1950a, 1950c) presents a study of the physiological mechanisms which he claims underlye many psychological and psychopathological processes. He has shown dominance effects of certain stimuli on the alpha rhythm in certain related areas of the cortex and in non-related areas. Secondly, by demonstrating the repetitive discharge of the cortex to regular stimulation, "cyclochronie", and the occurrence of this response after the cessation of stimulation, he has offered an interpretation of the occurrence

of chain reflexes and temporal conditioning, etc. The evidence and theory which he presents is supported by other evidence which he quotes. After demonstrating the conditioning of the spontaneous waves to sound, (see also Popov, 1950b, and 1950d.) he shows that a sound stimulus can be conditioned to cause the same effect in the parietal area of a rabbit as an electrical stimulus to the contralateral posterior paw (Popov, 1948b, 1951) and in other areas (Popov, 1948c). All the aspects of conditioning are examined including the effect of certain drugs to cause the reappearance of an extinguished response. One of the most important results that he obtained was that with extinction, the conditioned stimulus is not inhibited in the receptive area, but the response of the respective motor area was extinguished. This is contrary to the classical conditioned reflex theory.

Photic stimulation (a regularly flashing light) is used mainly in the study of evoked potentials in man. These are large and can be recorded directly, they are brought into relief by analysis. This has been demonstrated very clearly in the monumental work that has been proceeding in the laboratory of Walter in Bristol (Walter, 1946, 1949, 1950b etc.)

Walter reports that "subjective sensations associated with flicker (photic stimulation), include pulsating mosaics, whirlpools, kinaesthetic hallucinations and organised delusional states". (This is confirmed

by many experimenters, including myself). Individual differences are great , also the same subject at different times may organise the data in a completely different manner. There are correlates with maturity, psychological type and mood as well as wakefulness and the action of drugs.

Popov in establishing the principal of "cyclochronie" (1949) used light flashes one or two seconds apart. By shortening this time it has been found that the same phenomenon seems to occur at frequencies as great as 10 per second. "Photic driving" of the alpha rhythm by a light stimulus flickering at near alpha frequency has been noted in animals and men. Bartley (1936) and Bishop (1935) observed the phenomenon in unanaesthetised rabbits. It has also been observed in the monkey, cat and dog, both anaesthetised and not, Walter et al. 1944, Halstead et al. 1942.

In man, Adrian and Mathews (1934) noted that the rate of the alpha rhythm could apparently be raised or lowered to correspond with the frequency of flash stimulation of the retina. Toman (1941) and Walker et al. (1944) confirmed this. Halstead et al. (1942) report responses at triple the frequency of the flashes. Walter (1950b) has obtained the same results by stroboscopic photic stimulation, (the flashing is 'tied' on to the alpha rhythm), together with a lowering of the threshold of emotional response to pleasurable and unpleasurable stimuli. Bartley (1941) recognised two principle cortical responses to a succession of flashes to the

retina, a specific response to retinal stimulation, and a modification of the alpha rhythm. He concludes that the two markedly influence one another, and that the specific outcome of a series of flashes is dependent on the temporal distribution of the stimulus, its intensity and relation to existing acitivity. Thus the phenomenon of multiplied response to light flashes may be by change in either or both the specific and the alpha rhythm components of cortical potentials.

Walter and Walter (1949) report that responses to photic stimulation do not appear to "drive the alpha rhythm" since, with the eyes shut, activity at both stimulus and alpha frequency exist together appearing as beats in the primary record, and separately upon analysis. They also say that in most subjects voluntary mental activity involving visual imagery reduces the amplitude of the evoked response as well as that of the alpha rhythm. ~~After~~ After preliminary experimental study, a light, flashing at eight cycles per second with a light dark ratio equal to one, was chosen as the stimulus. The selection of frequency was determined by the fact that it must be easily recognisable amongst the spontaneous frequencies, not be so fast that the brain responds to sub-harmonics of various levels and not so slow that an easily recognisable wave form does not develope in a fairly short preparatory interval. The practical problems of constructing a tuned filter made it desirable that the frequency adopted was as high as possible.

(It was found that in three subjects, the alpha band of spontaneous activity included activity at eight per second, mainly at less than 10 microvolts before the experiment).

The experiment consisted of a verbal preparatory signal to press the key followed after an interval, randomly chosen, of between 2.5 and .5 second by the usual 'light' stimulus flashing at eight cycles per second. The cortical activity was recorded by two channels, one with the filter (an inductance-capacity type) in the output of the amplifier and the other unfiltered.

The general experimental details were as the same as previously. Two hundred trials were given to each subject. Care was taken to 'program' the intervals between successive trials, so that they varied between two and twenty two seconds in a random order of half second steps. A set of random numbers (Tippett) were used, and a given interval was not repeated in forty trials. The instructions given to each subject were as follows:

"I will tell you to press the key. The light will appear shortly afterwards. As soon as you see the light I want you to release the key as quickly as possible. After a short time I will say "press" and you are to press the key. When the light comes on you must release the key as soon as you can. Do you understand? I will say "press", you press the key. The light will come on, you release the key as soon as you see the light".

The group of subjects was divided into four with twenty subjects in each.

To each subgroup the filtered channel was connected differently.

1. to the occipital lead
2. to the parietal lead
3. to the central lead
4. the fourth subgroup was divided into four parts. To each section of five subjects the filtered channel was switched from one lead to another.
   a) between the occipital and parietal leads every twenty trials.
   b) between the occipital and central leads every twenty trials.
   c) between the parietal and central leads every twenty trials.
   d) between the occipital, parietal and central leads every ten trials.

The records were cut and examined in a similar manner to that of the previous experiments except that interest was centred on each reaction and not the intervening seconds.

The objects of the examination of the records were

1. to demonstrate that a consistent pattern of cerebral activity is built up as a result of the qualities of the stimulus.
2. to show that this is especially associated with preparation for the reaction.
3. to examine the form of the developement and to compare

the developement in the three areas.

Results. General.

The effect of filtering all except that in a narrow band from the activity of a lead is striking. The individuality of the record from different subjects was lost. This is especially noticeable during the course of the experiment when eight cycles per second activity is very much in evidence in all records. The amplitude of the eight cycles per second activity increased especially between the preparatory signal and the stimulus. Activity between the stimulus and the response is usually in phase with the stimulus. Between reactions an occasional burst, sometimes of high amplitude, appeared especially in the parietal record. It usually started one to two seconds after the reaction and was at times quite consistent. The burst lasted 1.5 seconds on the average and seemed to mirror the pattern observed during the previous reaction. Other activity at eight cycles per second which lasted from five to ten waves, occurred occasionally between reactions. There was however, nothing in the records to indicate that the association with the preparatory stimulus and response etc. was due to chance. The probability that the reactions sampled the occurrence of 8 cycles per second activity randomly, was found to be less than one in 10^8. (The chi squared test was applied to the proportions of reactions showing anticipatory activity and the proportions of the remaining time showing activity).

In this experiment the subjects' responses did not

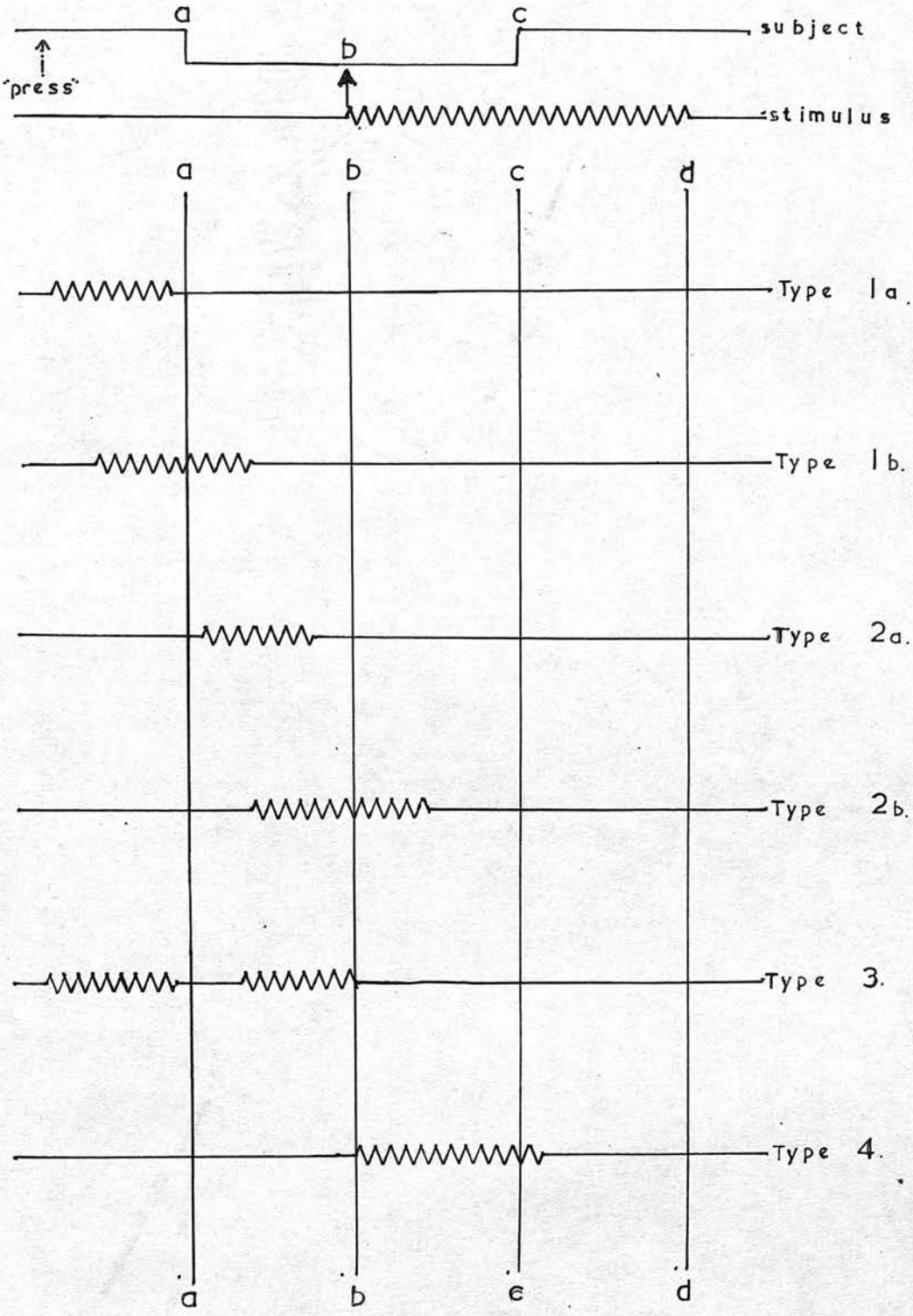


FIGURE 27.

The Classification of Patterns.

extinguish the light, and all leads, showed eight cycle per second activity between the response and the end of the stimulus. This was most noticeable in the occipital lead.

It was possible to isolate a small number of different patterns representing the positions of the burst of the highest amplitude viz:

Type 1a : activity occuring after the instruction to "press" but which blocked before the preparatory action of pressing the key.

Type 1b : activity starting as 1a and not blocking before the action of pressing the key.

Type 2a : activity starting after the action of pressing the key but which blocked on or before the arrival of the stimulus.

Type 2b : activity which started as in type 2a but which did not block on or before the arrival of the stimulus.

Type 3. Anticipatory activity which is divided into two distinct bursts, the first usually starting before the action of pressing the key and the second starting before the stimulus.

Type 4. activity starting after the stimulus but before the response.

These are illistrated in figures 27. Perpendicular lines a, b, c and d refer to the moments when the key was pressed, the light appeared, the subject responded and the

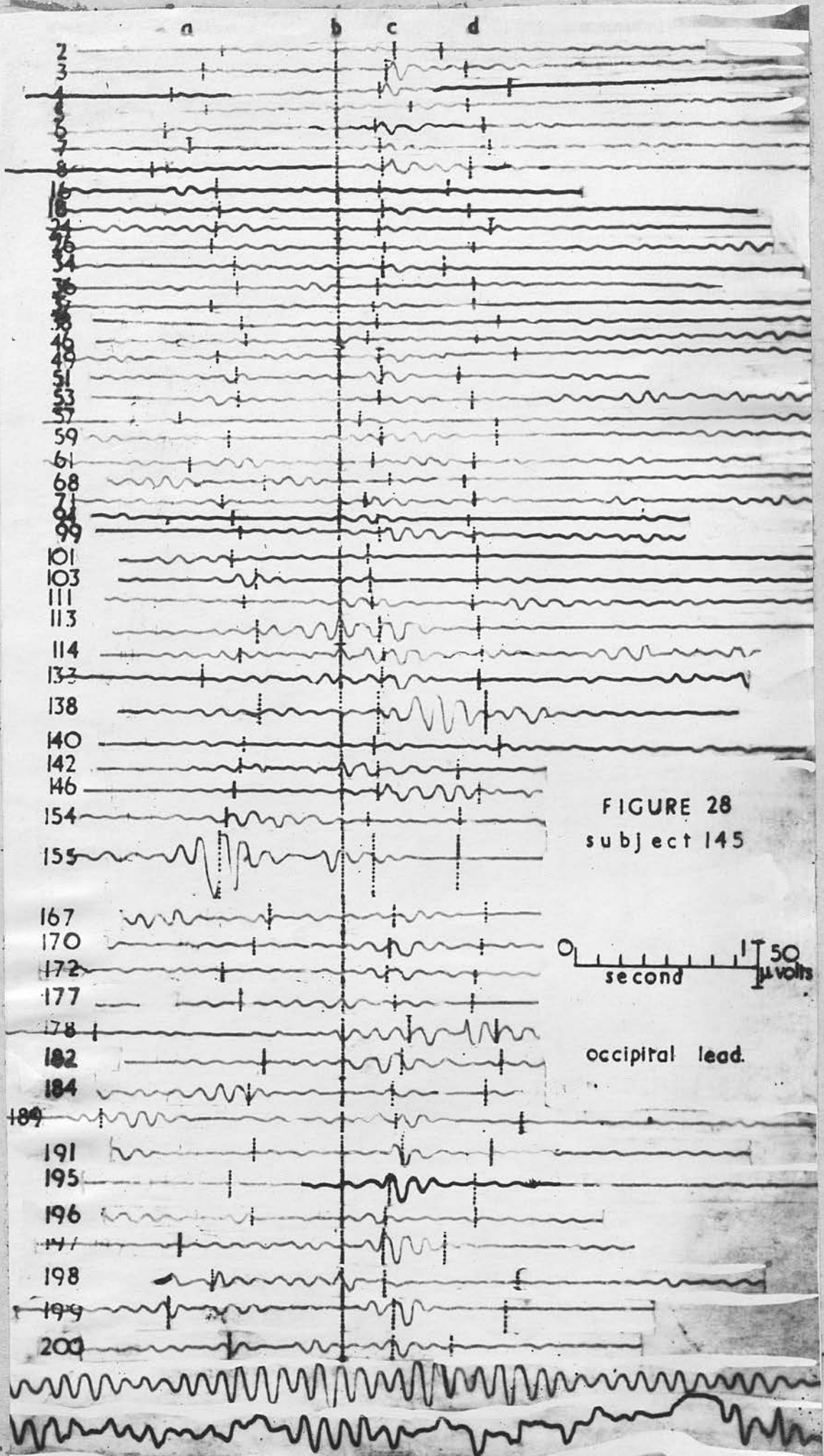


FIGURE 28
subject 145

end of the stimulation respectively. An anticipatory cerebral response is therefore defined as activity at eight cycles per second starting before b but not more than one reaction time before a. The patterns from the three areas did not show any distinctive qualitative differences. The amplitude of the occipital lead was always less than the others which were usually very similar to one another.

The results for the three leads are illustrated by figures 28, 29 and 30 for occipital, parietal and central respectively. The occipital results are presented in chronological order whilst the central and parietal records have been grouped for presentation according to pattern.

Figure 28 is composed of extracts from the record of the filtered occipital lead from subject 145. All the reactions showing any activity up to reaction 60 are shown and thereafter all those with amplitude of more than 20 microvolts. The records have been mounted beneath one another with respect to the onset of the stimulus i.e. the line b.

It will be seen that apart from an increase in amplitude there is very little indication of a progression as the experiment proceeds. The highest amplitude is reached between reactions 130 and 160 and for the rest of the experiment it remains fairly high. From the earliest reactions the highest amplitude per reaction was most often present in cd in the occipital lead i.e. in the interval after response and before the end of the stimulus. In

the later reactions this discharge starts slightly before the behavioural response i.e. in bc and lasts for three to four waves. During this period the subject is passive to the stimulus. This is common to the occipital leads of most subjects and is fairly often seen in the other leads.

The highest amplitude is seen in reaction 155. Other reactions of the same pattern are 51, 103, 114, 184 and 189. Patterns of type 1a (where the activity blocks before a) rare in this subject, are seen in reactions 16 and 101. Activity starting after a but blocking before b (type 2a) was seen in a greater number of reactions e.g. 61, 68, 154 and 198. In reactions 113 and 182 the activity persists after b (Type 2b). Two separated anticipatory bursts (Type 3) are seen in reactions 199 and 200. Most of the reactions after the sixtieth show activity anticipating the stimulus but with low amplitude.

The last two lines of record in figure 28 were made with the eyes closed after the experiment. They were both of the occipital lead, the first filtered and the second not filtered. These may be compared with no activity in the filtered occipital record at 8 cycles per second observable before the experiment.

⟵ There is a large increase in percentage time and amplitude of eight cycles per second activity in the record with eyes closed in all subjects and all leads.

The points noted above are seen in the majority of occipital records. The first appearance of eight cycles per second activity in anticipation of the stimulus

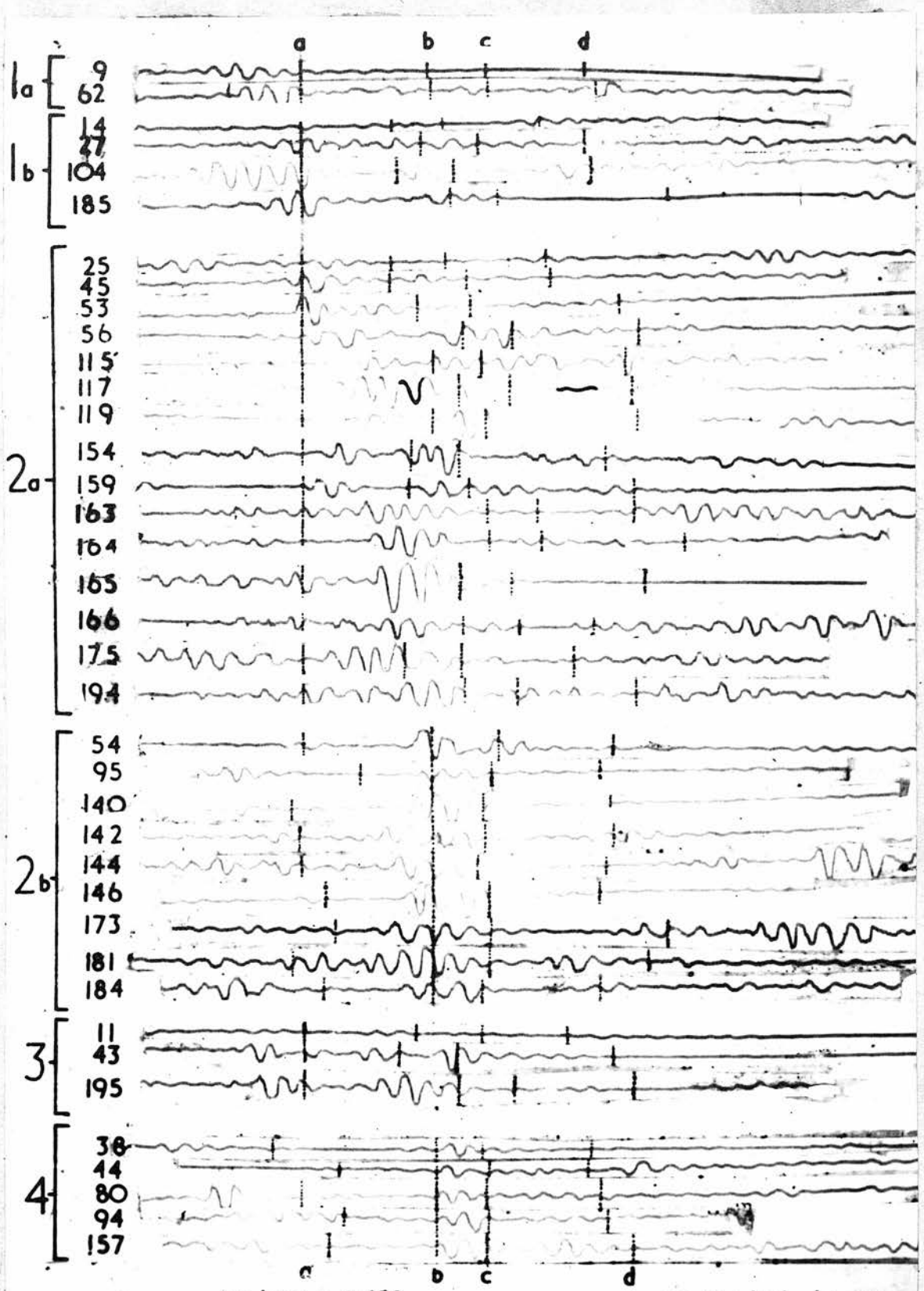

a
b
c
d
1a
9
62
1b
14
27
104
185
2a
25
45
53
56
115
117
119
154
159
163
164
165
166
175
194
2b
54
95
140
142
144
146
173
181
184
3
11
43
195
4
38
44
80
94
157
a
b
c
d
subject 158
parietal lead.
0
1 second
50 μ volts

FIGURE 29

was in the fifth reaction on the average (range 2 to 45) at first at low amplitude with a more or less gradual increase in successive reactions. Some activity at this frequency was present in 73% of all occipital records. Of these 80% were of less than 25 microvolts amplitude and 52% were less than 10 microvolts amplitude. The majority of occipital records showed the highest amplitude in c d.

The parietal and central leads showed an anticipatory response predominating.

The illustrations (figures 29 and 30) made with the records grouped according to pattern, (since the sequence of developement of patterns was no clearer than in the occipital record) emphasise the relationship of the anticipatory response to the reaction.

The six categories as defined above (viz. 1a, 1b, 2a, 2b and 3 and 4) have been used, the first five showing an anticipatory response. Interest in group 4 comes in phase analysis of the behavioural responses to be reported following this qualitive discussion. The reactions were chosen by selecting the first appearance of each pattern and thereafter others with amplitude over about 20 microvolts.

Compared with the occipital lead, the parietal lead shows different proportions of each of the patterns together with a higher mean amplitude. The difference between the amplitudes of the dominant burst and of the remaining activity in each reaction was greater in the parietal lead than the occipital and the patterns are therefore better defined. The central lead shows the highest

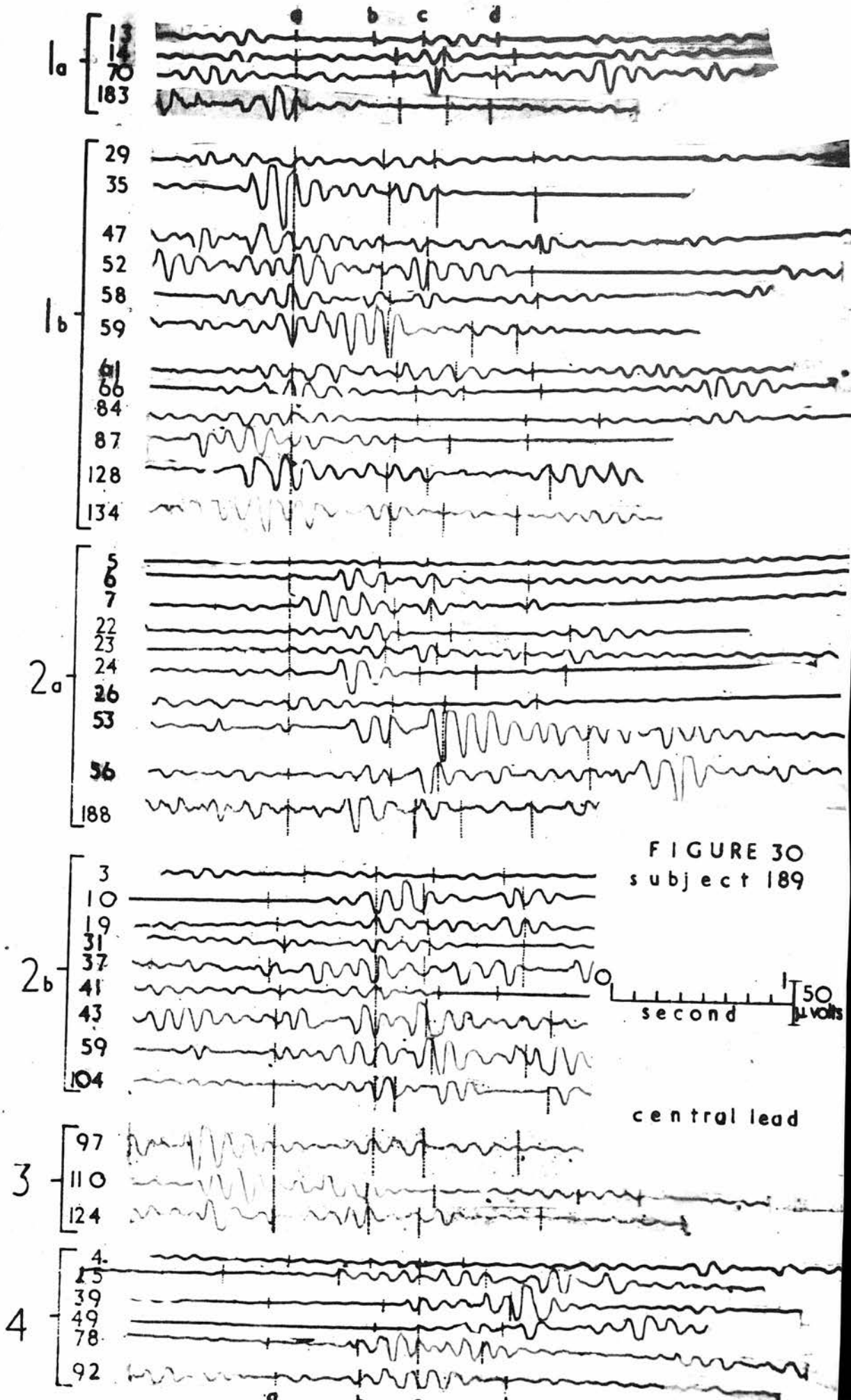


FIGURE 30
subject 189

amplitudes and the most contrast between dominant burst and the remainder of the activity, but the patterns were generally very similar to the parietal lead.

With subject 158 (figure 29) type 1a was the first pattern to appear in the parietal record after Right reactions. This was followed by types 3, 1b, 2a, 4 and 2b respectively. (The order in different subjects was not necessarily the same, almost all possible permutations were found. There was however, a tendency for type 1 (i.e. 1a or 1b) to appear first or early in the series, whereas type 2 (i.e. 2a or 2b) was sometimes not seen until the thirtieth reaction). Subject 158 showed type 2a most often. Consecutive responses occuring in the same group indicate that there may be a tendency for patterns of one type to occur in groups.

On the average the first appearance of eight per second anticipatory activity was reaction 14 in the parietal records and reaction 10 in the central records (ranges 5 to 43 and 2 to 37 respectively). In both leads a relatively high amplitude was present from the first appearance of activity.

Records of the parietal and central leads show no outstanding differences when they are recorded alternately from the same subject. Figure 31 is composed of extracts from the records from one of the group of subjects, Where the filtered channel was switched between the parietal and the central leads. Differences are

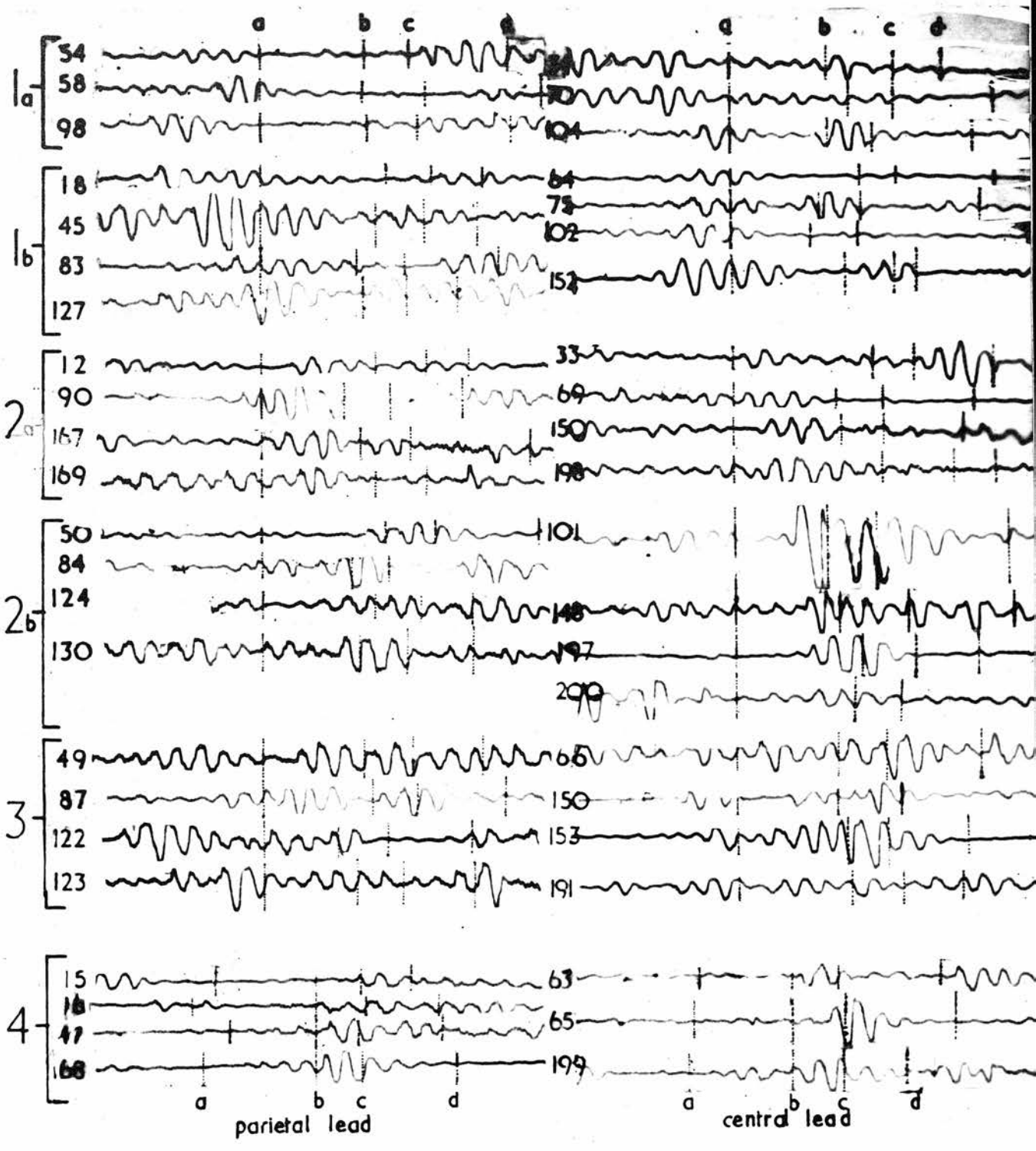


FIGURE 31

subject 234

0 1 second 50 μ volts

shown, particularly in the duration of the anticipatory response. Before line a in type 1a the burst is often longer but is more variable in the parietal than the central lead. The total amount of activity is greater in the parietal lead and the dominant burst is less outstanding (cf. types 1b for each lead).

It may be concluded that 1. A response of the brain showing the properties of a stimulus, can be shown to appear in anticipation of the stimulus after a number of repetitions of a preparatory signal and stimulus of recognisable qualities. 2. It is not clear whether the anticipatory response is associated more especially with the preparatory signal or the preparatory behavioural response. The anticipatory response of the brain may appear or disappear at the same time as the behavioural response (types 1a, 2a and 2b). When the cerebral response appears before the preparatory behaviour (pressing the key), as in types 1a and 1b, it may be associated with the preparatory signal. When, as in types 2a and 2b, activity occurs after pressing the key, it may be associated with either the preparatory signal or response but more especially with the latter. There may be reason to consider that [illegible] the two aspects are separable, since in type 3 reactions the anticipatory cerebral response blocked at or near to the preparatory behavioural response but before the arrival of the stimulus, and a second burst of activity appeared later but before b. 3. A cerebral anticipatory response is

variable in position, amplitude and duration for reasons unknown.

In the first few reactions very little or no activity is seen. The amplitude increases after the first appearance, taking more trials in the occipital than in the parietal and central leads. The latter shows greatest individual variations, some subjects show a high amplitude almost immediately, others take as many as forty reactions for an amplitude of 20 microvolts to be attained. 4. The form of the development of the patterns is not clear. Similar patterns recur in as many as ten successive reactions in some subjects, but in others the distribution of the various patterns appears to be variable. (For these reasons it was not possible to make full use of the records from the group of subjects in which the filtered channel was switched from one lead to another, and from which it was hoped to obtain information on the relative developement in the various leads. In the appendix to this section (appendix 3) a series of developmental stages in the relationships between the occipital and central leads are illustrated and described in detail. This development was observed between the central and occipital leads of a small number of subjects in whose record the presence or absence of eight cycles per second activity could be appreciated in the unfiltered lead. In these cases the simultaneous record for two leads could be examined. The limited number of subjects from which these conclusions could be drawn are

probably not representative of the sample as a whole and the conclusions must be viewed accordingly.

The relationship between the activity in the occipital and central leads seems to change in three stages

1. anticipatory activity not present in both leads at the same time. This includes the reactions in which no anticipatory activity is seen in either lead.
2. Activity present in both leads, but the patterns are different in each lead in a given reaction.
3. Activity present in both leads in the same pattern.

These stages are illustrated by figures 32 a, b, c and d. It has not been possible to demonstrate similar relationships between the parietal and either of the other leads. So far as can be seen, when activity occurs in both the occipital and the parietal leads the pattern is most likely to be the same from the begining of the series. There are many exceptions to this and there does not seem to be a development as between the central and occipital leads. One reason for the indeterminacy is ~~due to~~ the small number of records of the unfiltered lead capable of visual analysis.

CHAPTER 10

QUANTITIVE RESULTS.

In order to examine the relationship of the anticipatory response of the brain to the behaviour, an analysis of the filtered lead of all the reactions from each subject in groups one, two and three of the experimental sample has been made. The three groups were those in which the record was made with the filtered channel in one lead only for the whole experiment. The records of twelve thousand reactions were examined, four thousand from each lead. Each record was classified according to one of the six patterns described or 'rest', and the phase of the cerebral activity at the occurrence of the preparatory response, the stimulus and the response to the stimulus, i.e. at lines a, b and c, was noted. The phase was estimated and classified into one of seven categories. 0°, 45°, 90°, 135°, 180°, 225°, 270°, and 315°. The number of reactions falling into the various categories was found. The results are given in Table 2. Two further lines have been added, namely the number of reactions showing each type of pattern and the sums of the cell frequencies showing a particular phase at each line. For the purpose of this analysis the amplitude of the activity was not taken into account. If no activity was visible, the reaction was placed in the category "rest". Other reactions which came into this group are those which showed activity between c and d and not elsewhere.

TABLE 2

Phase and pattern-type analysis of reactions.

	type	Phase at line a								Phase at line b								Phase at line c								No. of reactions
		0°	45°	90°	135°	180°	225°	270°	315°	0°	45°	90°	135°	180°	225°	270°	315°	0°	45°	90°	135°	180°	225°	270°	315°	
occipital lead	1a	23	36	77	37	44	40	72	31	13	19	23	29	24	14	15	4	14	27	49	36	26	19	94	24	490
	1b	77	90	162	109	34	62	162	113	36	59	56	44	51	46	52	55	37	42	140	67	45	28	122	72	806
	2a	31	18	59	39	23	25	31	9	18	35	52	40	21	26	31	32	26	27	95	28	5	17	81	59	558
	2b	14	23	41	14	9	8	18	9	32	42	87	28	18	17	45	16	19	14	41	25	23	18	67	28	302
	3	9	23	67	18	29	27	59	14	41	49	22	27	10	28	22	27	4	9	49	27	32	22	45	21	294
	4									5	17	35	13	12	9	20	10	45	40	99	72	59	49	145	36	603
	Σ	154	190	406	217	139	162	342	176	145	221	275	181	136	140	185	144	145	159	473	255	190	153	554	240	rest 946
																										Σ 3999
parietal lead	1a	62	54	102	33	44	42	62	70	19	45	47	39	35	14	29	13	28	24	69	23	30	34	97	30	580
	1b	90	82	164	91	78	67	142	82	26	42	109	73	84	54	65	43	41	39	121	40	25	56	119	61	796
	2a	50	51	65	42	35	30	59	17	38	60	65	54	47	57	72	33	35	37	105	39	44	45	131	38	715
	2b	47	30	38	27	47	17	35	36	44	67	86	60	87	63	90	73	47	45	99	62	38	39	94	42	577
	3	56	45	87	42	32	33	90	67	35	54	84	51	50	36	65	57	26	35	105	37	41	45	86	51	540
	4									19	36	50	8	7	27	47	17	27	20	78	42	29	33	84	17	350
	Σ	305	252	456	235	236	189	388	272	181	304	443	285	310	251	368	236	204	200	517	263	207	252	611	239	rest 442
																										Σ 4000
central lead	1a	53	23	96	67	40	45	41	33	10	39	29	36	16	18	35	19	41	14	69	27	22	23	69	11	522
	1b	58	88	167	114	59	75	139	82	38	57	75	70	65	51	81	73	48	60	130	43	19	40	154	48	783
	2a	56	24	53	27	42	31	59	42	31	67	65	47	29	36	78	33	38	20	99	44	26	27	121	33	589
	2b	13	10	35	23	16	25	26	11	47	68	44	54	35	39	65	57	19	17	63	46	37	39	104	36	464
	3	20	38	84	39	26	23	105	60	45	51	62	43	44	41	78	42	18	42	137	41	39	38	66	27	434
	4									29	20	56	11	22	5	41	8	26	27	93	25	32	28	78	30	405
	Σ	200	183	435	270	183	199	370	228	200	322	331	261	211	190	378	232	190	180	591	226	175	195	592	185	rest 808
																										Σ 4005
		659	625	1297	722	558	550	1100	676	526	847	1049	727	657	581	931	612	539	539	1641	724	572	600	1757	664	total of columns

(numbers in cells are frequencies of occurrence)

1. An anticipatory response was present in 8450 reactions representing 70.4% of the total. Of these the most common pattern is that of 1b which occurred in 2,385 reactions i.e. 19.9% of the reactions. Type 2a was the next most frequent, being seen in 1,862, or 15.5% of the reactions. The proportions of type 1b are similar for all leads but there are significantly more of type 2a in the parietal record than in the occipital or central records.

2. The proportion of anticipatory responses which started before the preparatory response were compared with the proportion starting after the preparatory response (pressing the key). The proportions numbers of type one and type two were compared, by means of the chi squared test of independence, for the three leads. It was found that a significantly higher proportion of type one was observed in the occipital lead than in the central lead, and a very highly significantly greater proportion than in the parietal lead (from the chi-squared test $P < .01$ and $P << .001$ respectively) The occipital lead shows the anticipatory response associated with the preparatory signal significantly more than either of the other leads. The central lead shows the anticipatory response associated with the preparatory signal significantly more that the parietal lead ($P < .01$).

3. The action of pressing the key appears to affect the activities in the various leads differently. By comparing the relative proportions of patterns 1a and 1b in the three leads taken in pairs, the following results were obtained:

The occipital lead showed a significantly higher proportion of pattern type 1b than type 1a, compared with either the parietal ($P = .001$) or the central ($P < .001$) leads. No significant difference in the proportions of the two patterns was observed between the central and parietal leads ($P < .3$).

4. The arrival of the stimulus (line b) and the effect on the activity in the different leads has been examined in a similar manner. Patterns 2a and 2b were compared for the three leads taken in pairs by means of the chi-squared test. The occipital lead was found to be associated with pattern type 2a significantly more than either the parietal ($P << .001$) or the central ($P < .001$) leads. No significant difference was found between the parietal and central leads ($P < .8$).

SUMMARY:

Summary: Activity occurs in the occipital lead before the preparatory response but after the preparatory signal proportionally more than in either of the other leads. Of these, the central lead shows activity following the preparatory signal more than the parietal lead.

The activity in the occipital lead is less affected by the action of pressing the key and more affected by the appearance of the stimulus than either the parietal or central leads.

These results are in keeping with the accepted function of the underlying occipital and central areas. It is something of a surprise to find that the parietal

lead behaved more similarly to the central than to the occipital area.

The Phase Analysis.

The phase analysis of the electroencephalograms recorded during the reactions was made in order to discover whether the phase at which the stimulus occurs results in significantly different proportions of the patterns. Of special interest are the conditions: 1. for the persistence of activity and for blocking, and 2. for the behavioural responses.

For each of the lines a, b and c for each reaction, the phase of the cerebral activity was estimated where the line cut the electroencephalogram. The numbers of reactions falling into each of the seven phase groups were counted and shown in Table 2.

1(i). The results were compared with independence with the aid of the chi-square test. The aim was to discover whether the continuation of activity (2b) in the various leads was associated with the stimulus occurring at any particular part of the wave. The frequencies in each phase group for patterns 2a and 2b were compared for each lead separately.

It was found that the persistence of the activity in the occipital lead (pattern 2b) is significantly associated ($P = .001$) with the stimulus occurring at phases centreing on 90° and 270°. The central lead on the otherhand showed a significant association between these phases and the blocking of the activity (pattern 2a) ($P = .02$). This

may indicate general phase relationships of the two leads.

The occurrence of the two patterns in the parietal lead shown no significant difference ($P < .1$). The stimulus does not seem to affect the parietal record.

1(ii). Changes in the electroencephalograms as a result of the preparatory response (depressing the key) have been examined in a similar manner for patterns 1a and 1b. In the occipital record a significant association ($P << .001$) has been found between the phases of 180° and 235° and the blocking of the activity (1a).

The parietal records show a significant association ($P = .02$) of the phases 315° to 90° inclusive, with blocking of the activity (i.e. 1a). The central lead shows a significant association ($P < .001$) between phases 90° to 235° inclusive. The results with patterns 1a and 1b, though significant, are not conclusive since a consistent trend over the various phases was not observed. Both the effects of the light (patterns 2) and of the action of pressing the key (patterns 1) may be thought of as due to stimulation, external and internal respectively.

2. Phase and the behavioural response:

The phase of the activity and the two behavioural responses was examined in a similar manner.

The totals for each phase of the activity at each of the three lines (a, b and c) were obtained for all reactions. These were included in table 2 under the heading 'Totals of columns'.

It will be seen that for each line the cell

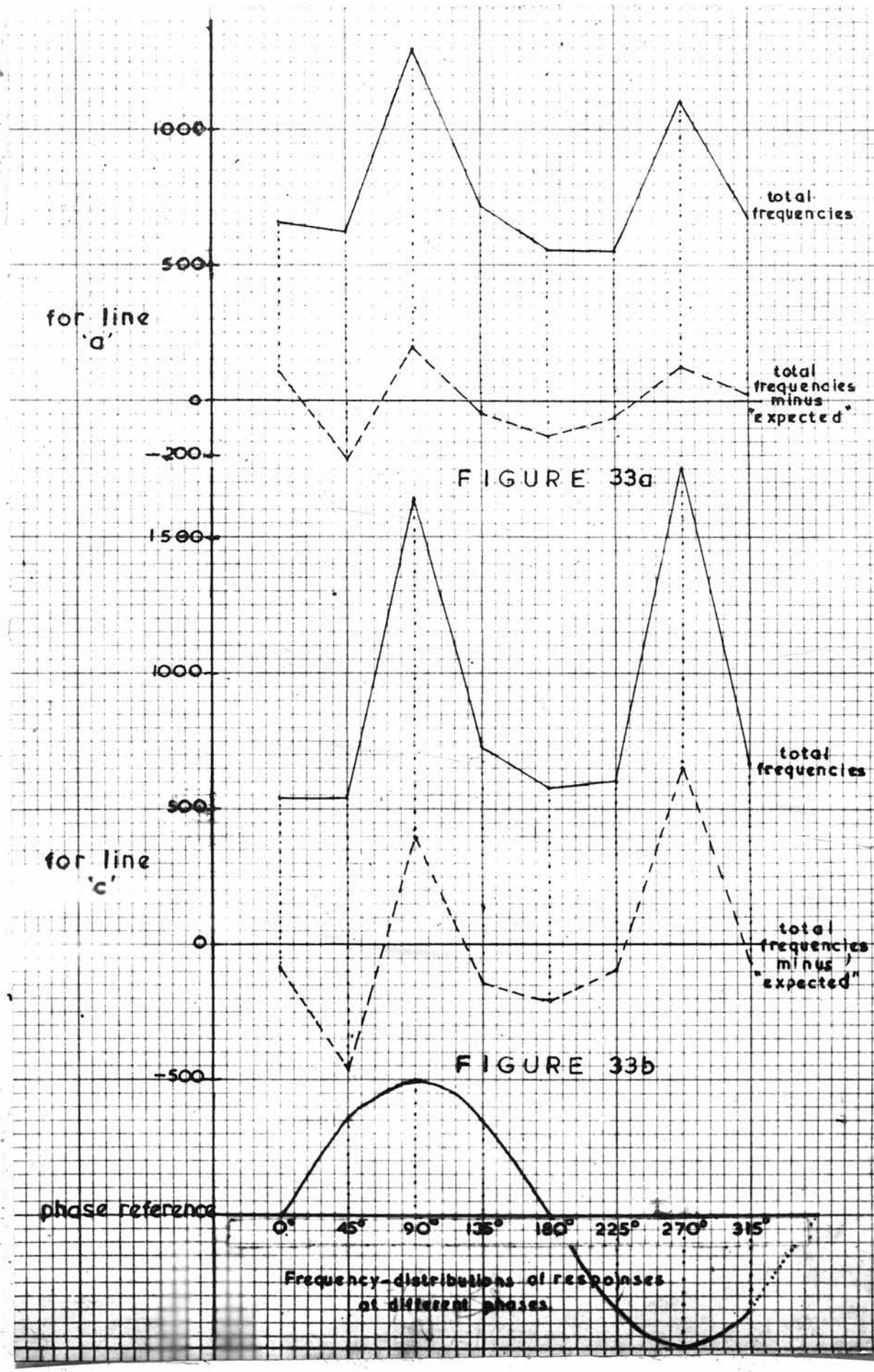


FIGURE 33a

FIGURE 33b

frequencies are much greater for 90° and 270° phase than for the remaining phases. Since the line 'b', showed the onset of the stimulus, was under the control of the experimenter and it appeared at random intervals, the working assumption was made that the unequal distribution of the phase analysis of the line b was due to the practical difficulties of analysis of phase. (It is easier to judge a phase to be 90° or 270° than any other. The next most easy phases to recognise are 0° and 180°. There would be a natural tendency therefore, to make errors increasing the numbers at these phases, despite the fact that the maximum possible care was taken in making each assessment.) The numbers obtained for line b were therefore assumed to be the result of this systematic error, and that a similar proportional distribution of errors was made in the assessment of the phase in the analysis of lines a and c. The results are illustrated in figures 33 a, b and c. The unbroken lines in figures 33 a, b and c represent the frequency distributions of the phase at which the behavioural response started. The phase of the cerebral activity is represented by a sinusoidal curve at the foot of figures 33b and c. Figure 33a shows the results for line a, figure 33b for line c and figure 33c for their sum. The lower dotted line of each figure is of the difference between the observed cell frequencies and the "expected frequencies", based on the above assumptions and calculated by proportion from the results for line b. The chi-squared test of independence was applied

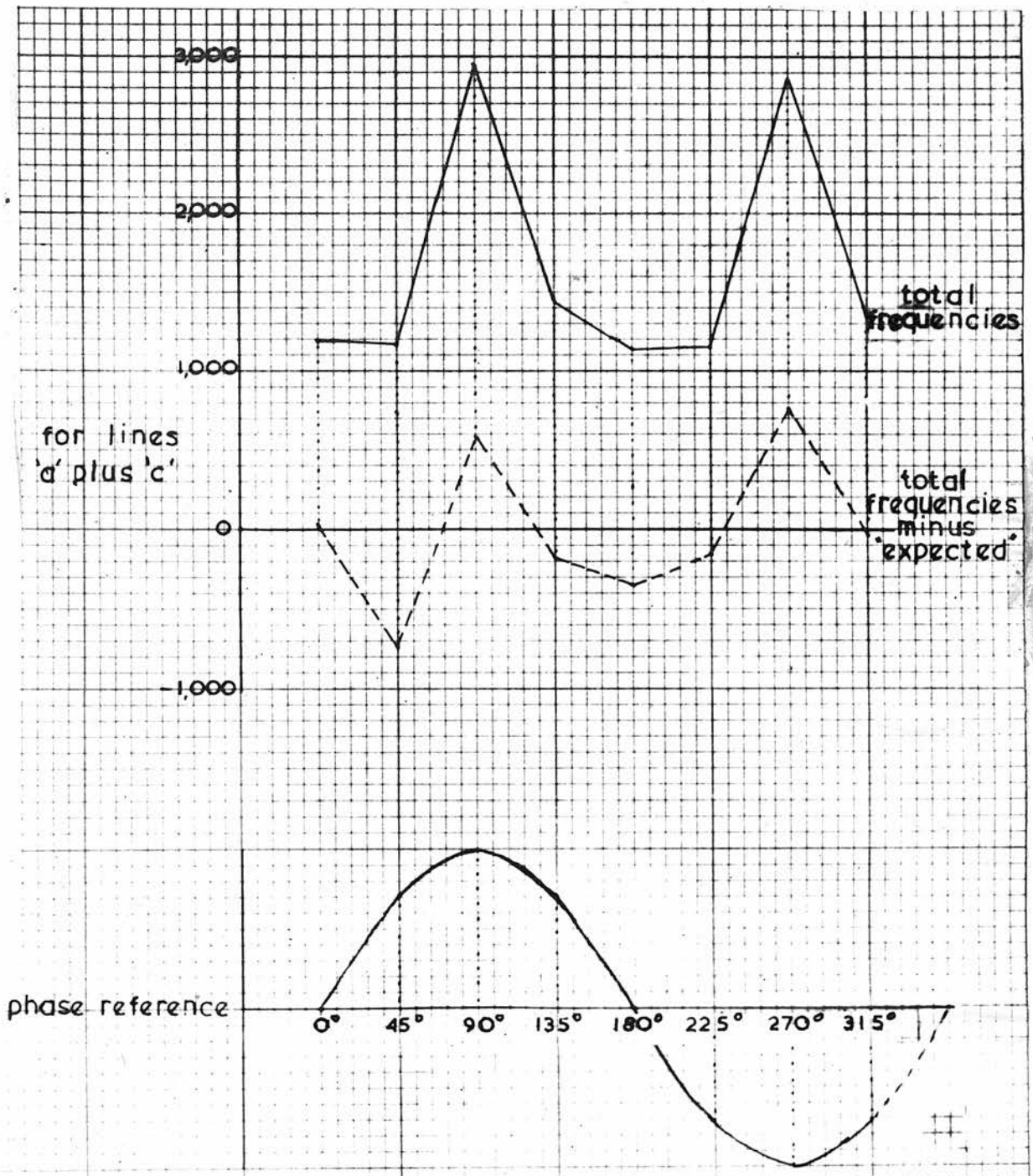


FIGURE 33c.
Frequency-distribution of responses at different phases.

to compare the observed and expected frequencies in each case. The value for χ^2 was found to be 184 for line a, 834 for line c and 835 for the combination. ($P < < < .001$). The association between phase and the behaviour is clearly demonstrated by these high values of chi-squared. From the figure 33 the systematic nature of the phenomenon is very apparent.

The behavioural response occurs associated with the cerebral activity at two points in the cycle, at 90° and at 270°. It is considered that the peaks may be the modes of two normal curves. The frequency of the activity is therefore 'doubled' by the most likely moments for a behavioural response, and, in terms of the response, the cerebral activity (sensory organisation) will be at most half a cycle out of phase.

In experiment one (section two of this paper) it was also found that the half cycle as well as the full cycle was a factor in the speed of response. Furthermore, a node was frequently observed in the alpha activity at the half cycle point in a long preparatory interval. The similarity of the two results is interesting. The demonstration that there is a tendency to respond at certain phases of the cerebral activity raises at least one important question. Since the cerebral activity has been shown to become related to the stimulus (the work of other experiments has been refered to earlier) and since the experimenter was exposed to a pilot light to indicate the

activity of the stimulus, is it possible that the cerebral activities of subject and experimenter could have ceased to vary randomly with respect to one another, and become, to some degree, synchronous?. If this occurred, it may cease to be possible for the experimenter to press the switch which presented the stimulus to the subject, at moments, independently of the phase of cerebral activity of the subject. This conclusion depends upon the autocorrelation function of the electroencephalogram, but in no way invalidates the experiment. It provides a clear demonstration of the importance to be attached to the use of automatic devices for the presentation of stimuli.

SECTION FOUR

CHAPTER 11

Factors affecting the Time of Perception.

The time of perception will depend on two main sets of conditions. It is necessary to say perception of what? (in terms of familiarity), and by what? (in terms of the state of the sensory perceptual organisations at that instant i.e. the expectancy).

Familiarity is important as Hebb has shown. In the perception of an organised whole which has been learned ("is familiar to such and such a degree"), the sensation and consequent activation of one cell assembly a may cause activity in the associated assemblies b and c etc., producing a phase sequence representing the whole without actual sensation of the entirety. The importance of expectancy and its place has been demonstrated in the

previous sections. There is also the possibility of interaction, the sensory organisation may be interfered with if the association areas were 'busy' with a phase sequence as a result of the just previous stimulus complex (i.e. the expectancy level may be low).

In reaction time experiments, with a simple set of stimuli (a light say), the familiarity is usually assumed to be high and constant, thus the time of perception may be defined from such an experiment in terms of expectancy. It has been found that the average value for reaction time is consistent, provided a large number of trials are used i.e. expectancy approaches an average value. Movement time is assumed to be constant.

In a human operator at a particular instant (0.3 seconds after the end of the preceding corrective movement), ~~a corrective movement),~~ a corrective movement having a predetermined time course (occupying about 0.2 second) may be triggered off (Craik 1947). The total length of a discrete cycle will be about 0.5 second. The figure of 0.3 second given by Craik refers to the so-called refractory phase of high-speed operation, during which the central mechanisms appear to restrict the transmission of the signal to the motor cortex, and no corrections, as a result of a stimulus intake, are made during that time. This is not refractoriness of the motor organisation, since an organised motion or state of acceleration may be continuing during the 'refractory phase'. This time during which the central mechanisms maybe said to be still

engrossed with the preceding reaction, (rather than use the misleading term, refractory phase) seems to occur irrespective of the familiarity, or expectancy of, the preceding stimulus, and is, therefore, a function of the act of perception.

Welford (1952) summarises the work of several authors, that when two stimuli, requiring hand action, are presented close together, the reaction time is frequently longer to the second stimulus, than to the first. He goes further and puts forward a theory that the time required by the central mechanisms to deal with information provided by a stimulus, and to initiate a response to it, is, on the average, the same, whether the stimulus comes close to another or not. This he calls the 'organising time'. Normally it will be the same as the average reaction time to a single stimulus. The central mechanisms are liable to become engaged, by stimuli fed back from the motor response, particularly from those parts of it where there is rapid acceleration or deceleration of movement, or where some definite sound or visual or tactile change is produced. "The perception of such feedback data will also require central organising time", he says.

The evidence of Craik, Vince, Telford, Bates, Poulton and Hick working at Cambridge is consistent, he concludes, with the Hypothesis that no two central organising times can overlap. Therefore, information from a stimulus, arriving while information from a preceding stimulus is

being dealt with, has to be held in store until the central mechanisms are free.

It must be pointed out that these assertions refer to experiments in which intervals between stimuli were variable, and the subject does not expect the small interval between them, though, seemingly, the subjects were aware that such things might occur, through practice trials at the task. Had this fact been anticipated by the subjects i.e. had the total stimulus pattern been expected, they would have been able to incorporate the two actions into one whole.

If we are to consider the reaction time, as a measure of expectancy, how does the minimum time compare with the central organising time? By definition, the reaction referred to by Welford and Craik, are without preparatory signal and take, on the average, 0.28 second (Welford) which is the value he gives for the central organising time. If the reaction time is less than this as a result of a preparatory signal (average 0.18 second Woodworth) then expectancy must include some aspects of central organising time, i.e. by virtue of the expectancy some of the organisation is accomplished before the actual stimulus occurs. It appears then, that some of the activities of organisation (Welford), must be the same as, or equivalent to, those that I have suggested represent expectancy (called sensory organisation after Hebb). This is an important conclusion. It indicates further lines of research and dictates further restrictions to be kept in mind when talking about expectancy.

In addition to the foregoing, we have some evidence, mainly in the form of a hypothesis by Stroud (1949), on the intake of such information before a response.

Stroud suggests the existence of a 'psychological moment' in perception. The psychological moment is a period of time during which all ingoing stimuli are summative, and that this is equal to about one-tenth of a second. By this hypothesis, it would not be possible to separate stimuli which arrive during one 'moment'. The evidence for such an assertion is not very good but there seems to be very little evidence against it. The notion of a tenth of a second moment was first introduced by McCulloch and Pitts (1947). Walter (1950), for slightly different reasons, also considers that a scanning rate of ten per second is a good estimate of the speed of operation of the occipital cortex, if it is thought of as converting spatially dispersed information into a time series. (Such a mechanism would be most economical in 'components' and space).

The Brücke effect offers some indication of the 'psychological moment' hypothesis, but not proof. If light is flashed at a rate of about nine per second (varying with different subjects), and the subject is asked to match a stationary light to its apparent brightness, it is found that the flashing light appears up to four times brighter at the frequency, circa nine per second, than at either slightly higher or lower frequencies of the same light and with the same light dark ratio. Bartley (1941), considers this to be a function of the alpha rhythm. It can be shown

(Hoagland 1947), however, that the rate of alpha activity is changed by the administration of thyroid or increase in bodily temperature, whereas the frequency of flashes for the Brücke effect remains constant. Stroud offers evidence of the effect, but not proof. Referring to reaction time, Stroud (1949), says that in a typical experiment the subject has no chance to synchronise the stimulation to the 'moments' so that the phase relationship of stimulus and 'moment' is determined by chance. "To react, the subject must become aware of the stimulus" and this must, by Stroud's theory, be accomplished in some 'moment'. It is very unlikely that there is any awareness of the content of each 'moment' until the end of it, i.e. until the whole of the stimulus excitation which it is going to represent, has occurred. There will therefore, be some definite time after the cue before any definite action can be taken. All other things being equal, and under perfect conditions, without synchrony but with a constant 'moment' frequency, the net result would be a square distribution of reaction times with a range of one 'moment'.

Under good laboratory conditions, with a short (one to two seconds) but not constant preparetory interval, the reaction time to a visual stimulus has been found to have a mean of .18 second. This would include a value of approximately .05 second, the mean increase in reaction time, due to lack of synchrony with the 'moments'. Thus, if there is a comparable system in the human, approximately similar in most respects that the mechanism producing 'moments' does

not opperate, we would expect the mean reaction time in this system to be less than that for the visual system by .05 second, other things being equal. The need for 'moments' in the hypothetical transformation of the spatially displayed information, reaching the brain from the eyes, into time series, is explained by Wiener (1949) as the necessity for sampling. In this way, a continuous input can be approached. But if the time of each sample is too short, the sampling will be bad. The average of the inputs will not be reached in a precise manner. Therefore, for the information to be really significant there must be a waiting period. In reaction time experiment by Todd, quoted in Woodworth (1938), stimuli were either light, sound or electric shock, or combinations. To the light alone, the mean was .18 sec, to the sound or shock the mean was .14 sec.; using the light simultaneously with either of the other two as a stimulus, made no difference to the reaction time, but sound and shock together gave a reaction time of .13 second. When all three were used simultaneously the response time was again .13 second. The combination of sound and shock may provide a channel which does not use a time average system. At least, it appears that .13 is the minimum average reaction time, and, comparing it with the minimum for light i.e. .18, this is confirmation of the idea of a .1 second averaging process (psychological moment in preception). Negative evidence comes from the fact that though the other two stimuli added, shorten the reaction time, the addition of a light to the stimulus complex does not significantly

affect the answer. At threshold values of the three stimuli separately, the differences between the reaction times disappear (Wundt, quoted by Woodworth, gives the value for the reaction time to liminal light, sound and touch to be about .33 second), however, under these conditions, longer time averages are taken anyhow, and the difference would be expected to vanish.

It is concluded, that the average minimum time to respond to a light stimulus is .05 second longer than the average minimum possible (using a combination of shock and sound stimuli), and that this evidence is in accordance with the concept of a psychological moment in perception. Neither the auditory mechanism, or that stimulated by the shock would appear to need the transformation necessary in visual perception from a spacial display into a time series.

If it can be demonstrated, that cerebral activity during a reaction shows consistent features, and if they can be related to the behavioural effects, the concepts will not only be given physiological reality, but the foundations of a detailed study of stimulus response problems will have been laid.

Two exploratoy experiments were planned and carried out, to examine the possibility that the electrical activity of the brain may reflect the properties of organisation, thought to be a necessary variable intervening between stimulus and response.

IN SUMMARY.

The central organising time between stimulus and response has been referred to. One property of the brain, is that it seems unable to deal with more than one organising process at a time. Whilst one is active, others must be held in store. The use of a preparatory signal reduces reaction time, and the effect is said to be due to some of the organisation being accomplished before the stimulus arrives. This seems to be the purpose and definition of expectancy.

CHAPTER 12

EXPERIMENT FOUR

In this experiment, twenty subjects were used, all responded by raising the finger from a key, when the light stimulus appeared, exactly as in the previous experiments. Each stimulus was steady for the present experiment. Electrodes were placed on the left occipital and left central areas, and recordings made throughout the experiment. Subjects were given the same instructions as in the first experiment in this paper. They were told to respond as quickly as possible as soon as the light came on, and then to depress the key again. The instructions went on: "Some stimuli may arrive soon after the one before. I want you to respond as quickly as possible to every stimulus by releasing your finger from the key and then pressing it again". No preparatory signal was given. The intervals between stimuli were randomised with the

same pattern as in the last experiment and varied between 22 and 2 seconds. The following exceptions were made: In randomly chosen order, and at the 21st, 27th, 38th, 46th, 60th, 65th, 72nd, 78th, 87th and the 100th reactions, the stimulus was made to follow the onset of the stimulus of the previous reaction by intervals of .075, .125, .175, .225, .275, .325, .375, .425, .475 and .525 second. Thus the subject was still busy, in most cases, with the first reaction when the second stimulus arrived. This was accomplished by means of an oscillator arranged so as to deliver two stimuli only. In these special reactions the subjects' response did not extinguish the light (the light dark ratio was 1). By connecting the oscillator in a different manner (see appendix 4) it could be used as a variable time delay, and following the 112th, 121st, 135th, 141st, 148th, 159th, 163rd, 179th, 184th and 192nd reactions, the stimulus was arranged to appear at one of the above intervals after the subject had replaced the key from the previous reaction randomly chosen. In this case, the subjects response extinguished the stimulus. (In the rush of the experiments, setting and resetting the oscillator sometimes lead to as much ± 5% inaccuracy in the interval, especially in those less than .2 second. If a response was given to the first of a two stimuli only, the interval was repeated once at the end of the experiment. The results fall into two parts. a The variation of organisation times due to the proximity of the previous reaction, and b, the electroencephalographic results of the remaining reactions

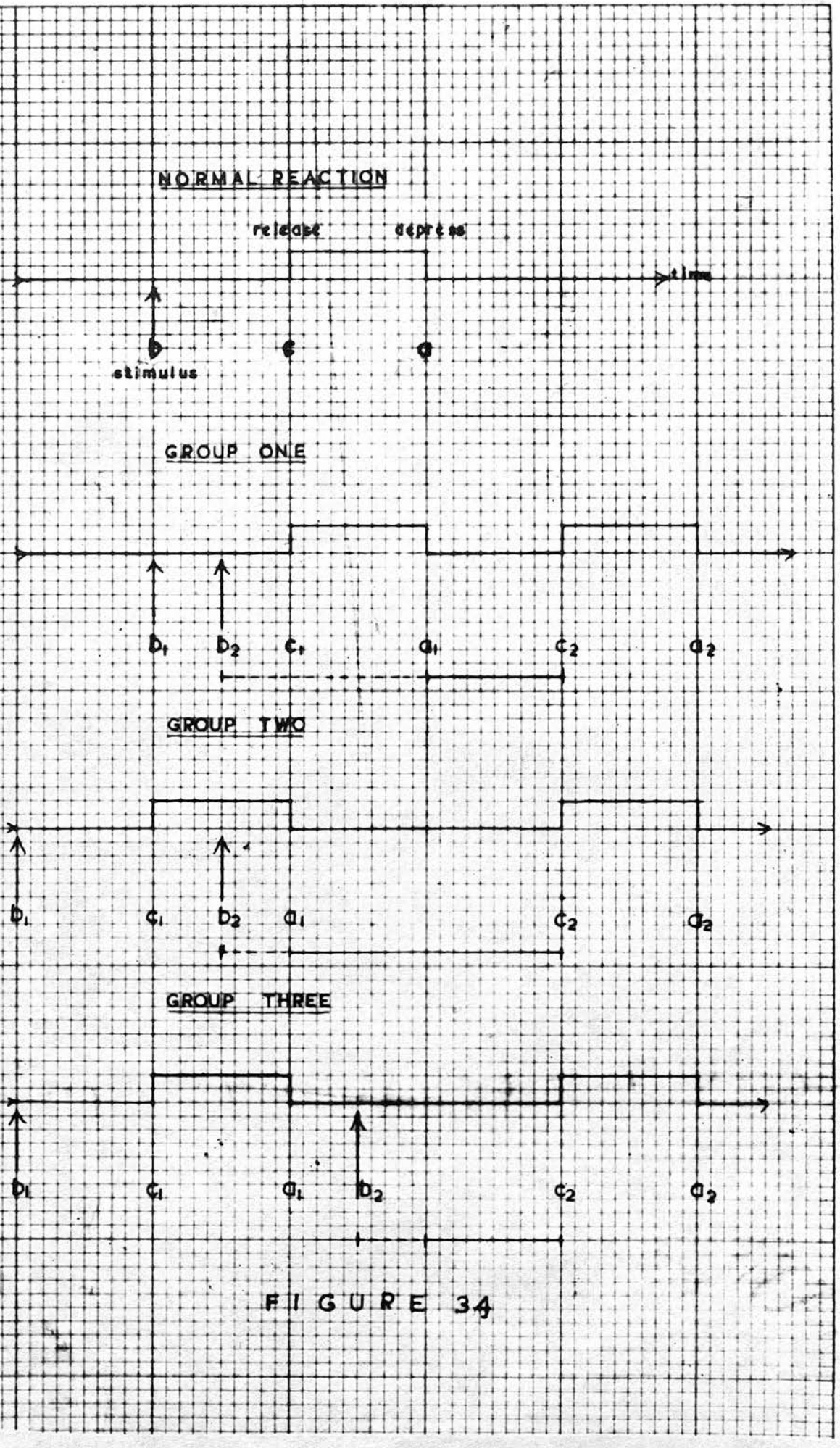

NORMAL REACTION
release
depress
time
b
stimulus
c
a
GROUP ONE
b1
b2
c1
a1
c2
a2
GROUP TWO
b1
c1
b2
a1
c2
a2
GROUP THREE
b1
c1
a1
b2
c2
a2

FIGURE 34

Due to the small number of reactions in the first group, it was not possible to draw any conclusions from the cerebral recordings during these reactions, but the evidence from the remainder, i.e. b', may be compared with the results of a')

a The Organisation Times.

In figure 34, the actions of the subject in the usual reaction, are diagramatically represented, together with the three categories of possible occurrence of the second stimulus (b2). The actions and the stimulus have been named a, b, and c in conformity with the practice in this paper, a refers to depressing the key, b to the stimulus and c to releasing the key. The suffixes 1 and 2 refer to the first and second reactions of a pair respectively, (The diagrams in figure 34 are not to scale)

Group One. a. The first step is to see whether the arrival of the second stimulus, b2, before the first response, c1, affects the occurrence of c1. The task is complicated by uncontrollable factors. In a long reaction time, (b1 c1) it is possible for b1 b2 to be large, but if b1 c1 is short, a long b1 b2 will result in b2 arriving in c1 a1 (i.e. group 2) which excludes the results from this consideration. There will, therefore, be a tendency for a positive relationship between b1 c1 and b1 b2 to be shown, which is a function of the method. This sort of error may be reduced by plotting b1 b2 against b2 c1, but it cannot be removed.

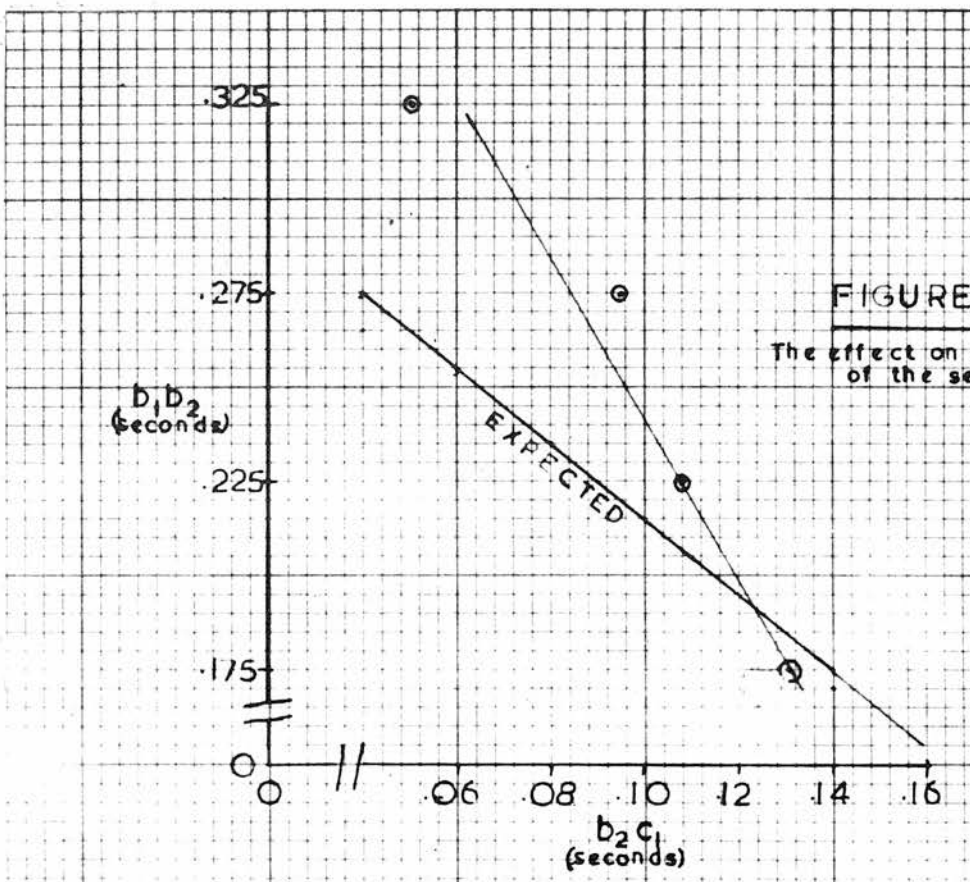


FIGURE 35a

The effect on the first reaction of the second stimulus.

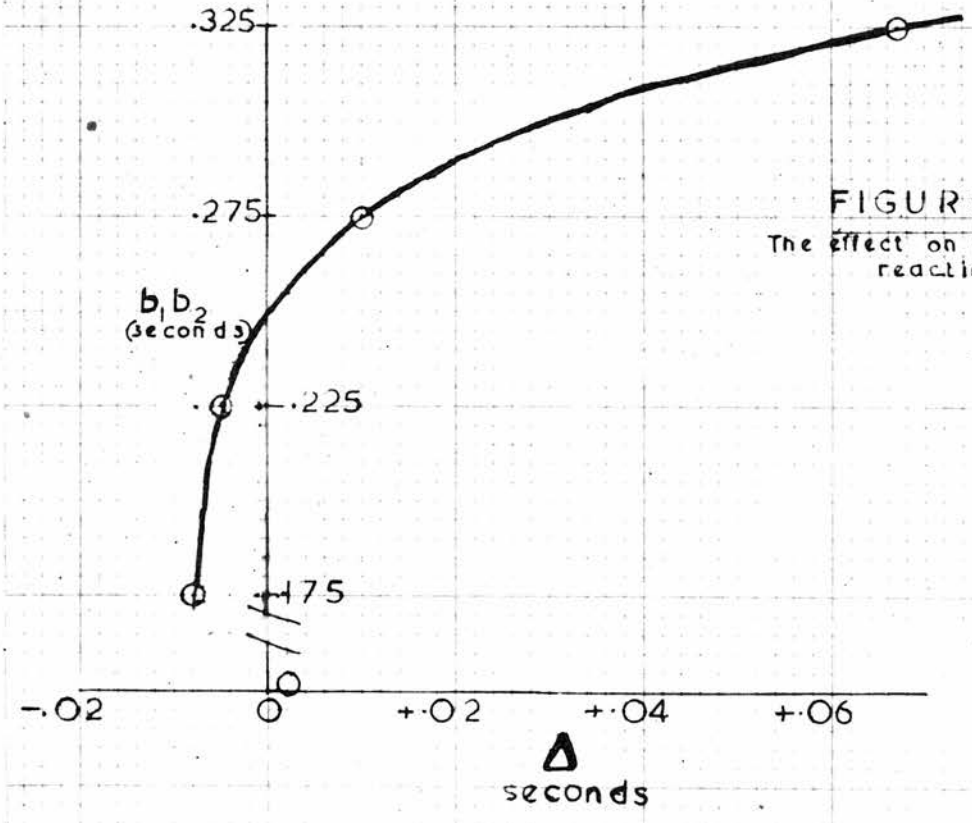


FIGURE 35b

The effect on the second reaction

The times b1 b2 have been plotted against b2 c1 in figure 35a. The line marked 'expected' was derived from the mean reaction time of all subjects for the normal reactions (see figure 34). This was found to be .315 second and being b1 c1 should equal b1 b2 + b2 c1. A straight line has been drawn in the general direction indicated by the four points obtained from the data (all values of b1 b2 of .125 and less were refused by all subjects i.e. one response only was made to the pair of stimuli). It is thought that a curve, asymptotic to some value of b1 b2 near to .35 second, would be most likely, but the straight line drawn, as a first approximation, shows the discrepancy between the results and the 'expected'. It is clear that if b1 b2 (i.e. time between stimuli) is above .19 second, the reaction is longer than might be expected, and that with separations less than this, the reaction is shorter. The difference at .175 second is not significant, but the systematic trend in the values lends weight to the result. The significance of the point of intersection, and the fact that the value is close to that for the simple prepared reaction time, is not clear.

b. The effect on the second reaction of the proximity of b_2 to b_1:

For each subject, the mean reaction (RT) was subtracted from the values for c1 c2 first (i.e. c1 c2 - RT = Y). It was found that the average of the resultants was .054 second. The distribution was, however, bimodal. Analysis showed that 40% (8) of the subjects gave a mean value of -.007 (SD = .003) second. This is within the limits of experimental error. The mean for the remaining 12 was .107 sec (SD = .05).

Thus, it would appear that part of the experimental group responded, with the organising time to the second stimulus delayed until the begining of first action of the first reaction i.e. releasing the key, c1. The results of the second group of subjects were then investigated further, and it was found that a1 c2 - RT (= Z), gave a value of -.060 second (SD .018). From this, it appears that these subjects delay the organisation of the second reaction until just (.06 second) before depressing the key at the completion of the first reaction.

In order to observe the variations in these differences (i.e. Y and Z), 1. in relationship to the proximity the two stimuli (b1 b2), and 2, in relationship to the nearness of the second stimulus to the first response (i.e. b2 c1), the values of the deviations of the above differences from their respective means, were found for each response. Whether Y (i.e. c1 c2 - RT) or Z (i.e. a1 c2 - RT) was used, depended upon the group to which the subject was found to belong (as above). The average deviations (of the Y's and Z's, as the case may be) have been plotted against b1 b2, in figure 35b, and b2 c1, in figure 36a. The ordinate, representing the average deviations from Y's and Z's, has been named $\triangle$ for convenience. It is assumed that $\triangle$ will represent the variation from the mean of the length of the organising time. It will be seen from figure 35b, that a smooth curve can be fitted by eye to the data. The curve indicates that, for separations of the two stimuli of more than approximately 275 milliseconds, the organising time increases very nearly proportionally to

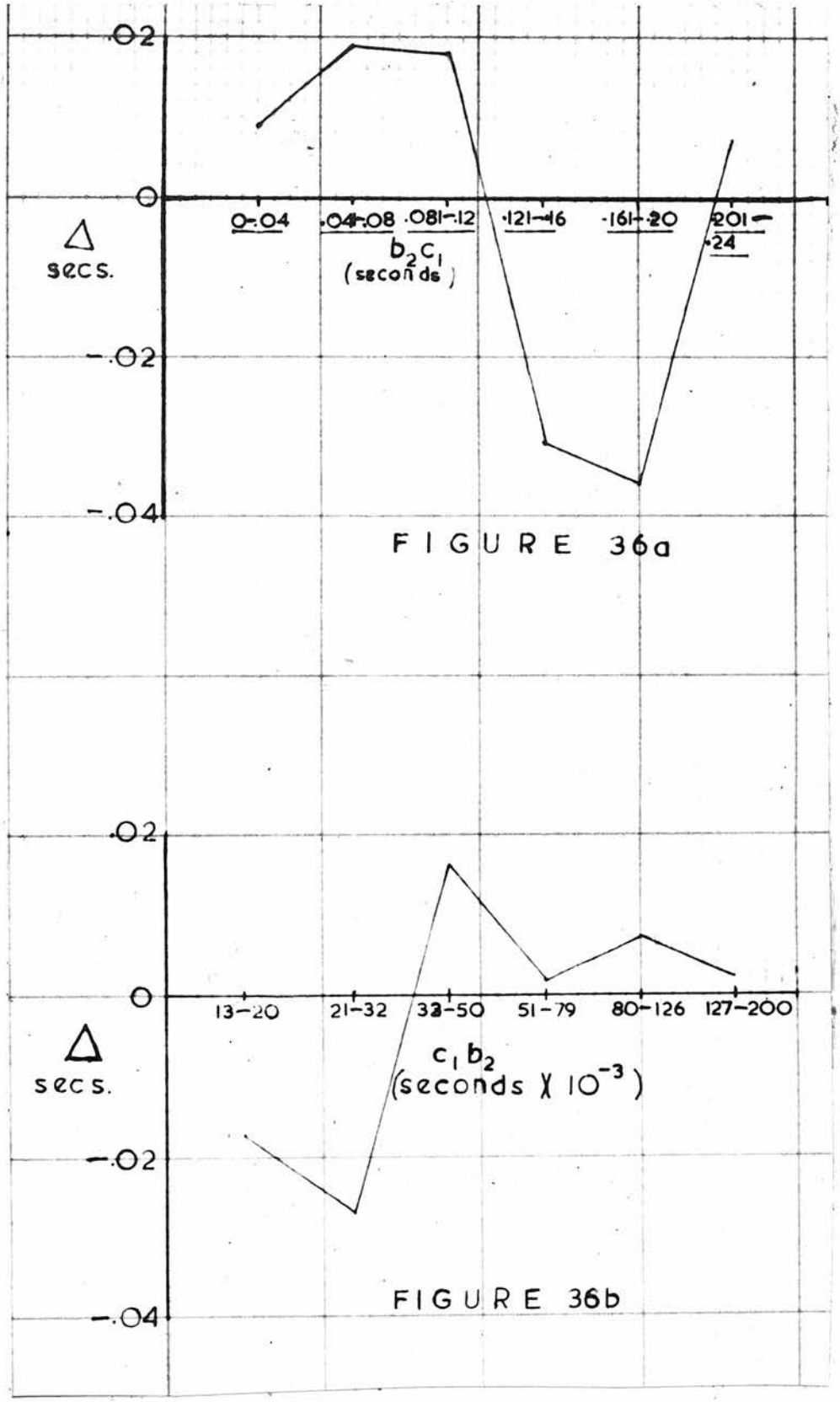


FIGURE 36a

FIGURE 36b

the increase in separation. The results indicate that should a subject give a longer than average reaction time at a given instant, it will also be long, in the next instant i.e. in the next possible moment that a reaction could take place. This follows from the fact that for $b_1 b_2$ b_2 to be greater than about .3 second, the reaction time to the first stimulus must be longer than average. The values of b2 c1 were spread over a range of approximately .2 second. The results were grouped with intervals of .04 second, and the value for Δ for each of the groups was found and plotted. From figure 36a, it will be seen that provided b2 and c1 are separated by more than about .1 second and less than .2 second, the organising time is significantly lessthan the mean. If b2 c1 is less than .1 second, the organising time is increased slightly above the mean. The change between these two states is sharp and clear, though the total range of values in the organising time is only 16 per cent of the mean reaction time.

Group Two.

When the second stimulus occurs after the release of the key but before its replacement, the stimulus appears to be stored until the key is depressed again, and the organising time starts from that moment. This was shown as follows: The values for the mean reaction time to the normal reaction were subtracted from the time b2 c2, and a1 c2 for each subject. The averages of the results are .115 sec (SD = .17) and -.002 sec (SD = .008) respectively. It was,

therefore, concluded that the organising time starts at c1. The variation in the organising time to the second stimulus, due to its proximity with c1 and a1, was examined.

The deviations from their mean (of - .002) of the values of a1 c2 - RT were found for each subject, and plotted, in figure 36b, against the values of c1 b2 which were grouped in logarithmic intervals of .2. The class intervals have been marked in seconds for each of reference. Logarithmic grouping was used because the distribution of the values of c1 b2 was skewed to the smaller end of the scale. Its effect was to make the number of values falling into each group more nearly equal. From the figure, the organising time for the second reaction is reduced, if the second stimulus follows the first response (i.e. c1 b2) by less than .03; it is slightly increased if c1 b2 lies between .03 and .05 second, and is, thereafter, not significantly different from the mean (i.e. $\triangle$ is approximately zero).

To a second stimulus arriving after the release, but before the depressing of the key, not only the proximity of the previous action of releasing the key, but the nearness of the action of depressing it, affects the duration of the central organising time. The variations of $\triangle$, with respect to b2 a1, is illustrated in figure 37a. The range of variation of $\triangle$ is greatest with this variable.

There is a significant increase in the organising time when the separation of b2 and a1 varies between approximately .05 and .1 second. At other times of separation, the organising time is usually less than in the

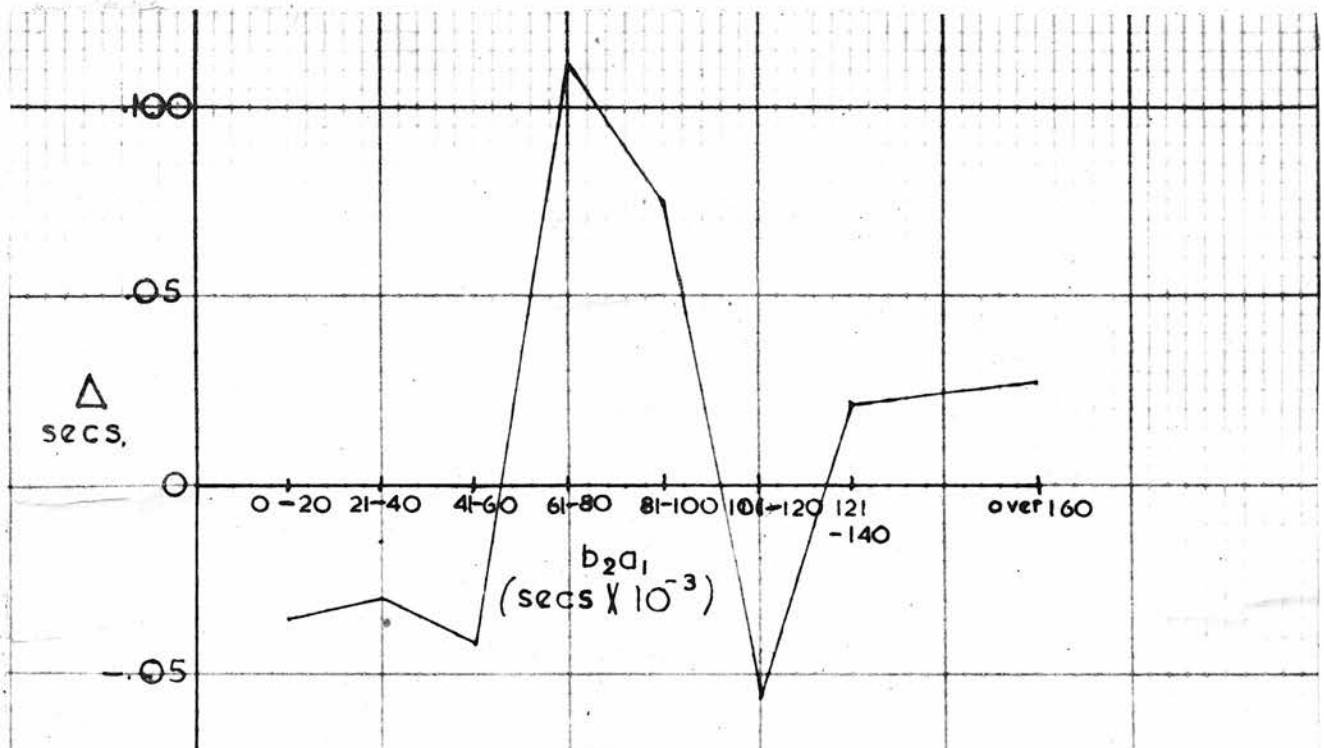
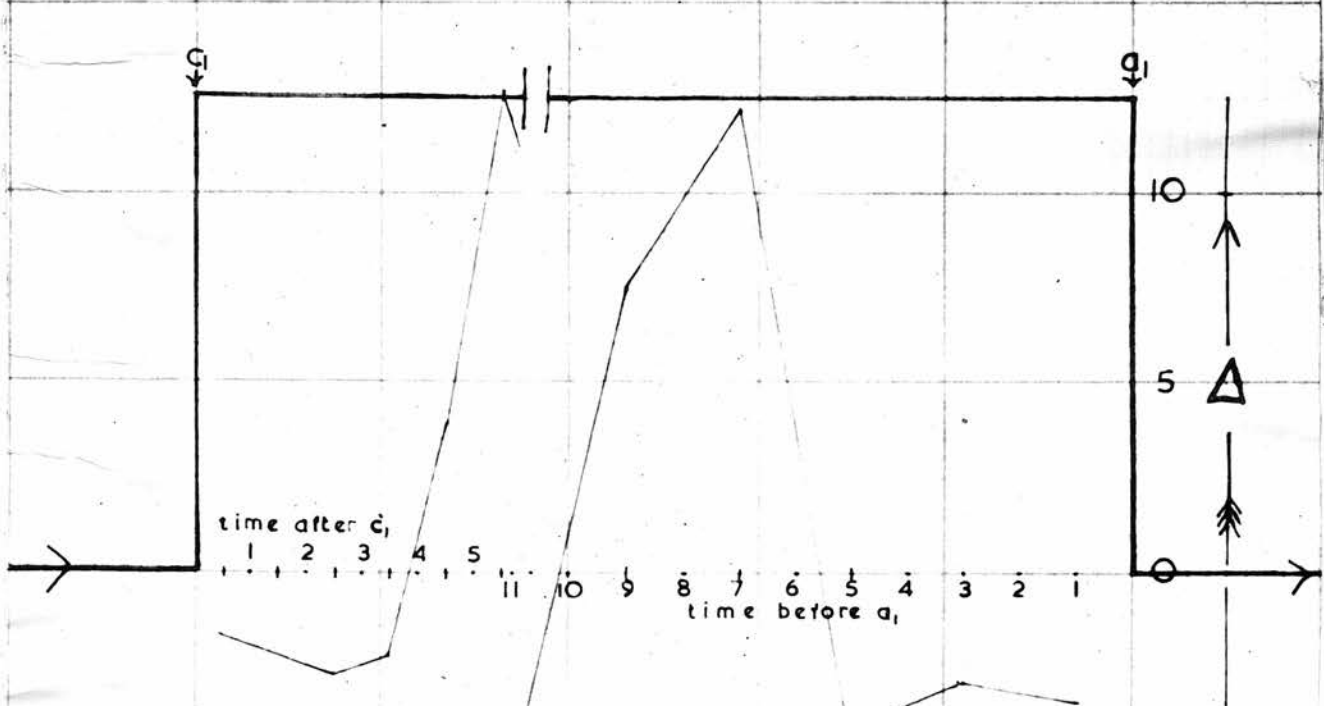


FIGURE 37a



all times in seconds X 10^{-2}

FIGURE 37b

normal reaction.

Summary of Group Two

The results, illustrated by figures 36 b and 37a, showing the effects on the organising time of variations in the separation of b2 from c1 and a1 respectively. The same values of △ were used in each, however, in most cases, a decision may be made as to whether it is the proximity of c1 or a1 which is the governing factor. From figure 36b, c1 has little effect if the separation is greater than .05 second, and, from figure 37a, a1 has little effect after perhaps .1 second. Each set of results was examined to see whether the value of △ was most likely to be affected by c1 or by a1 i.e. three categories were used, either c1 b2 less than, or equal to .05 sec, or b2 a1 less than, or equal to, .1 second, or both. In figure 37b, the effect of the stimulus arriving between c1 and a1, has been illustrated by using this classification. Where △ is liable to be affected by the proximity of b2 to both c1 and a1, the it of △ has been included in both of the two sets of results. With the exception of point b2 a1 = .11 second, 10 per cent fell into both categories, and 5 per cent were excluded altogether from either, by the limits chosen. Including the point b2 a1 c1 = .11 second, 30 per cent of the values fell into both categories. The change of grouping to linear for c1 b2 has altered the values, but not the shape of the curve. If the phases of the two curves are equated, the value of c1a1 a1 becomes .14 second. The significance of the variabilities of △ is not clear at this stage.

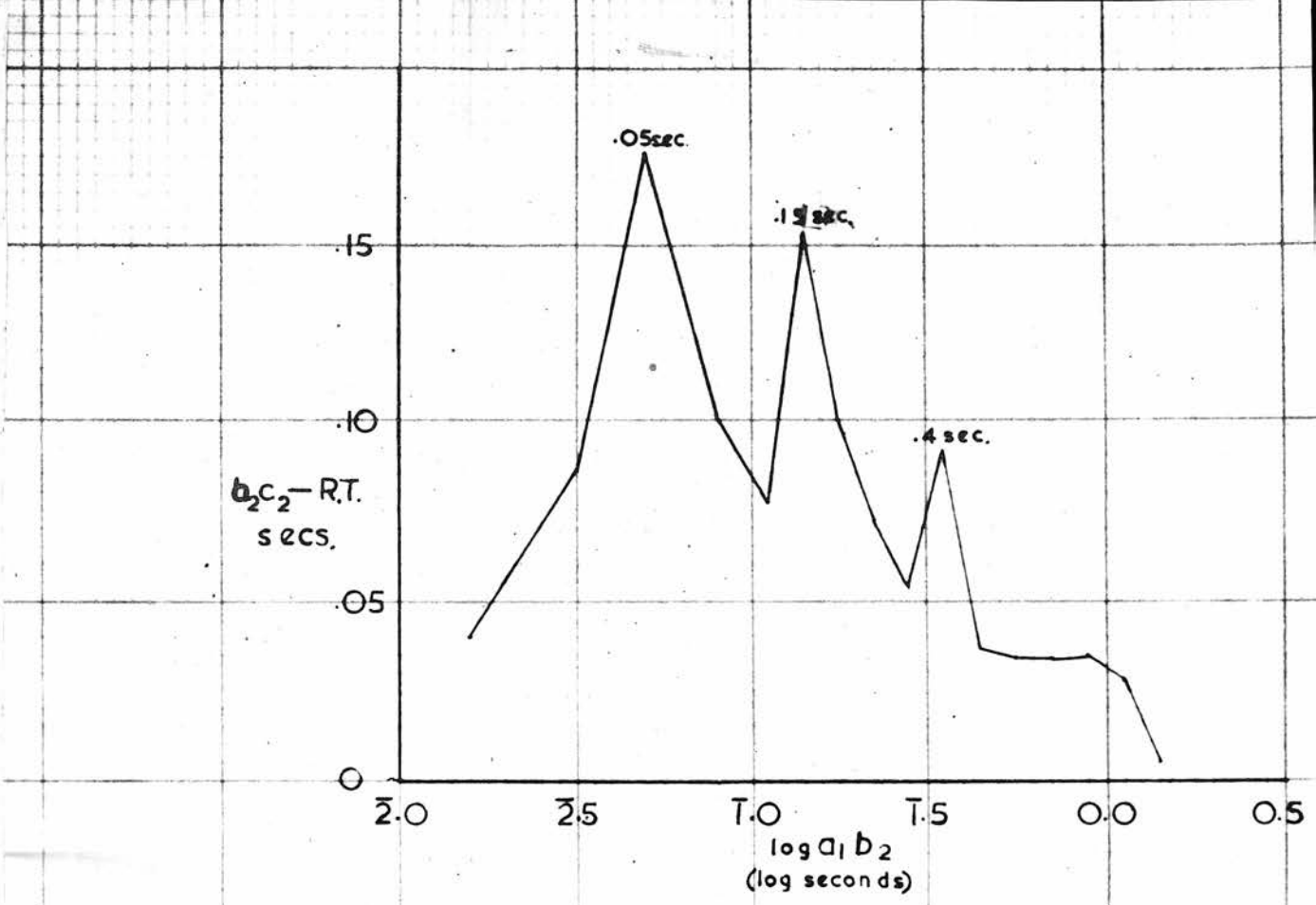


FIGURE 38a.

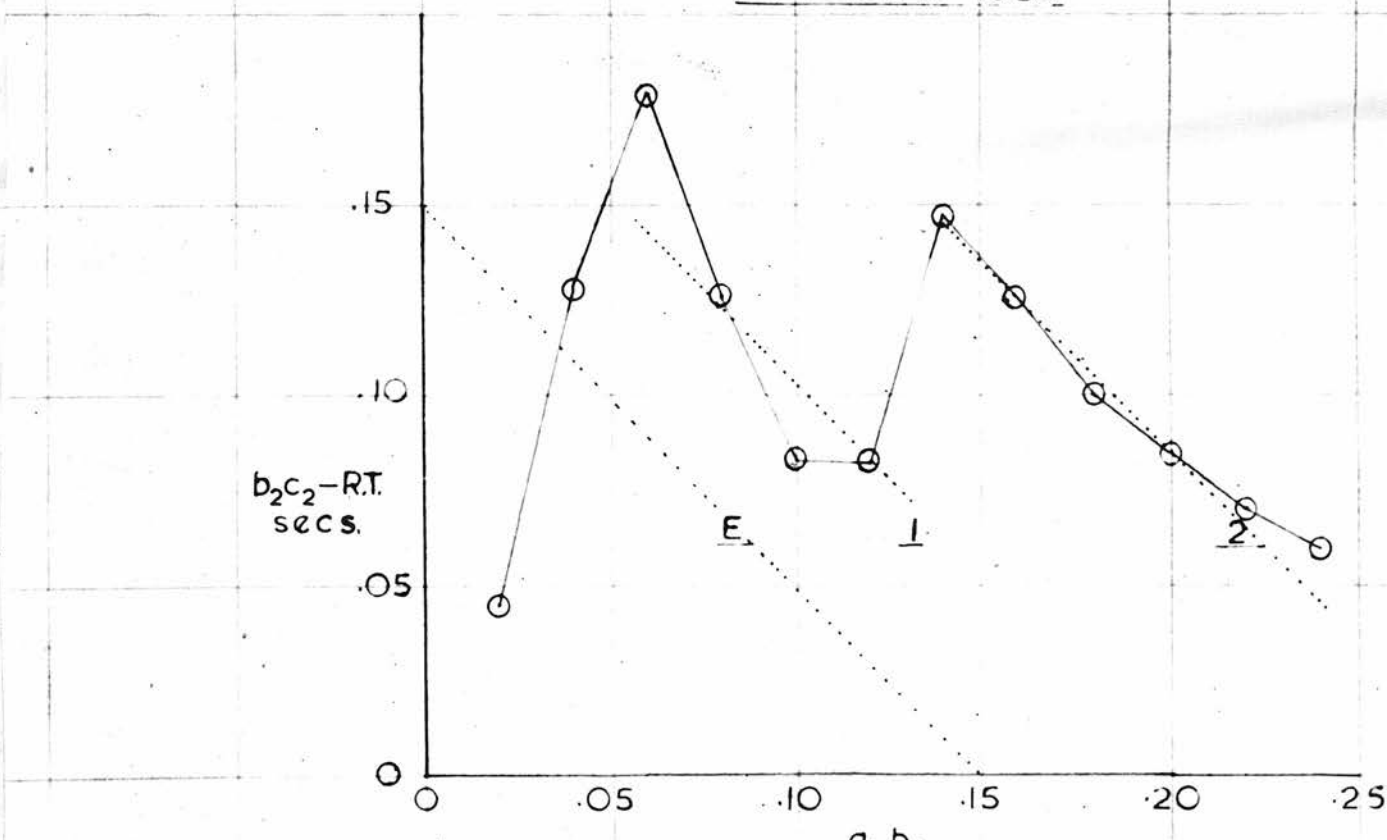


FIGURE 38b.

Group 3.

The final stage in the analysis, is of the data when the second stimulus b2 occurred after a1. The values for a1 b2 were fairly evenly distributed, but, because of the large range of a1 b2 before the effect of the first of reaction on the second, is reduced to zero, a logarithmic scale has been used for a1 b2. The results are illustrated in figure 38a. The size of the log class intervals was .2 from $\bar{2}.0$ to $\bar{1}.0$, and .1 thereafter (The small absolute size of .1 log unit between $\bar{2}.0$ and $\bar{1}.0$ made this necessary). For each class interval, the mean value of (b2 c2 - RT) has been plotted. (RT refers, as usual, to the mean reaction times for each subject in the normal reaction and, in this case, it was subtracted from each value of b2 c2 before the results were grouped and their mean taken).

Three peaks are present and significant in figure 38a. They occur at points representing values of a1 b2 (the time between the end of the previous reaction and the arrival of the second stimulus) of approximately .05, .15 and .4 second, respectively, and are progressively lower in amplitude. The mean value of the increase in reaction time (b2c2 - RT) was found to be .09 seconds, and values do not approach zero until the separation between a1 and b2 reaches one second.

At certain times of separation, the increase is much greater, These times are shown by the peaks. The sharp rise and relatively slower fall of those at .05 and .15 second would seem to indicate that the central organisation

from stimuli falling at these times after the last reaction, is 'held over' until some time later. If this is the case, then from these points the two variables (viz. b2c2 - RT and a1 b2) will bear an inverse linear relationship to one another, such that a given increment in one will result in a reduction of the same amount in the other.

In order to test this hypothesis, figure 38b was drawn from the same data. Values of (b2c2 - RT) were grouped, in this case, in .02 sec. steps of a1 b2. The first two peaks are included. In accordance with the idea above, the slope of the left hand side of the peak should be very steep, and that of the right hand side should be a straight line at 45° to the ordinates. Dotted lines 1 and 2 have been drawn to represent what should happen at the right hand side. It will be seen that the degree of agreement is high between all the factors of the second peak, which shows a maximum at a1 b2 = .14 second with this grouping of data. The ascent is steep, and the fall is very nearly a straight line with a slope of 45° to a1 b2. The first peak on the other hand, does not agree on either point. (The dotted line 1 is drawn at 45° to a1 b2 going in each direction through the point (.09 .1125) given by the mean of the values, for the four points from the peak to the trough, of this part of the curve). The differences of the observed from the expected rise are small but systematic, as are those in the fall. It seems unlikely that the differences may be explained by the experimental error or that the hypothesis offered is

the best possible, though an alternative may be hard to find.

Welford (1952), considers that internal "stimuli" fed back from a response are dealt with by the subjects central mechanisms in a way similar to that for stimuli given by the experimenter. .."we should expect that those fed back at the begining of the response would 'capture' the central mechanisms for a brief period ... when a morse key is pressed, sensory impulses likely to 'capture' the central mechanisms might be expected at the begining of the movement when the bottom stop is struck and, again, when the hand is brought to rest after the key has been released. The possible occurrence of a 'high point' of stimulation at the end of a movement, has the important implication that a short refractory period may follow the making of a response, and cause some delay in the response to a second stimulus given by the experimenter". Welford gives the lengths of the brief periods at the begining and end of the movement to be .15 second. In this experiment, the situation was reversed and the movement was "release - press", but by the nature of the equality given by him to the two periods the difference should not matter.

In the results given under Groups One and Two, it was not found necessary to invoke 'feed back' to explain the delay in responding to the second stimulus. This, however, may also be a function of the experiment, since the mean total movement times i.e. c1 a1, to the first stimulus times were found to be .151 and .153 seconds for each

group respectively (the third decimal place is not significant). This value (.15 sec.) is the same as that given by Welford (Loc cit.) Thus the end of the movement would, on the average, be at the same moment as the end of the refractory period, following the begining of the movement on Welfords theory, and the results would fit either equally well. However, in Group three and in particular with reference to the initial .15 second after the end of the first reaction the theory and the observed data from the present experiment fall very widely apart. The mean time between the begining and end of the response i.e. c1 a1 in this part of the experiment was .19 second so that the first "refractory" period should have elapsed by a1. This being so we would, on the basis of theory, expect the results to produce a line starting at a1 b2 = 0 , (b2 c2 - RT) = .15 ; and having a slope of - 1 downwards. This has been marked as a dotted line, E, in figure 38b. Clearly, some alternative should be sought.

The feedback suggested may take some time to arrive and not be expected to start at a1. The order for such a time would, however, be more like .05 sec, than the .15 second required, if the data is to show the necessary characteristics of slope etc. outlined above. If the first peak is a function of the feedback, perhaps it will be necessary to change the concept of "refractoriness", such that the closer the second external stimulus and the fed back stimuli are together, the greater the delay of the response to the external stimulus, and that if left unfacil-itated

by the second stimulus, the fed back stimuli decay in a curve approximating to the fall from the first of the two peaks. If present, this would seem to be a most unfortunate mechanism so far as the efficiency of the human is concerned, but it is non the less possible if an explanation for the second peak and the striking conformity to a theory of 'holding in store' can be found as well.

One theory, mentioned already, requires visual stimuli to be 'held in store' until the end of a fixed period; Stroud's Theory of moments prescribes, that the stimuli be held for .05 sec, on the average, and .1 second at the most. The data can be considered to fit some aspects, notably the first peak and the trough at .1 second after a1, but it is considered better, that judgement is deferred.

In Summary, the response to the second stimulus, following the end of the first reaction by less than one second was delayed, when compared with a single reaction. The amount of the delay depends upon the 'following time' of the second stimulus to the first reaction. Certain features (notably peaks) are present, to suggest that the phase relationship of the arrival of the stimulus and some internal mechanism may be important.

b) The electroencephalographic results.

The cerebral activity, recorded from the occipital and central areas in the course of the foregoing experiement, has been analysed for consistent features of phase during the various parts of the reactions.

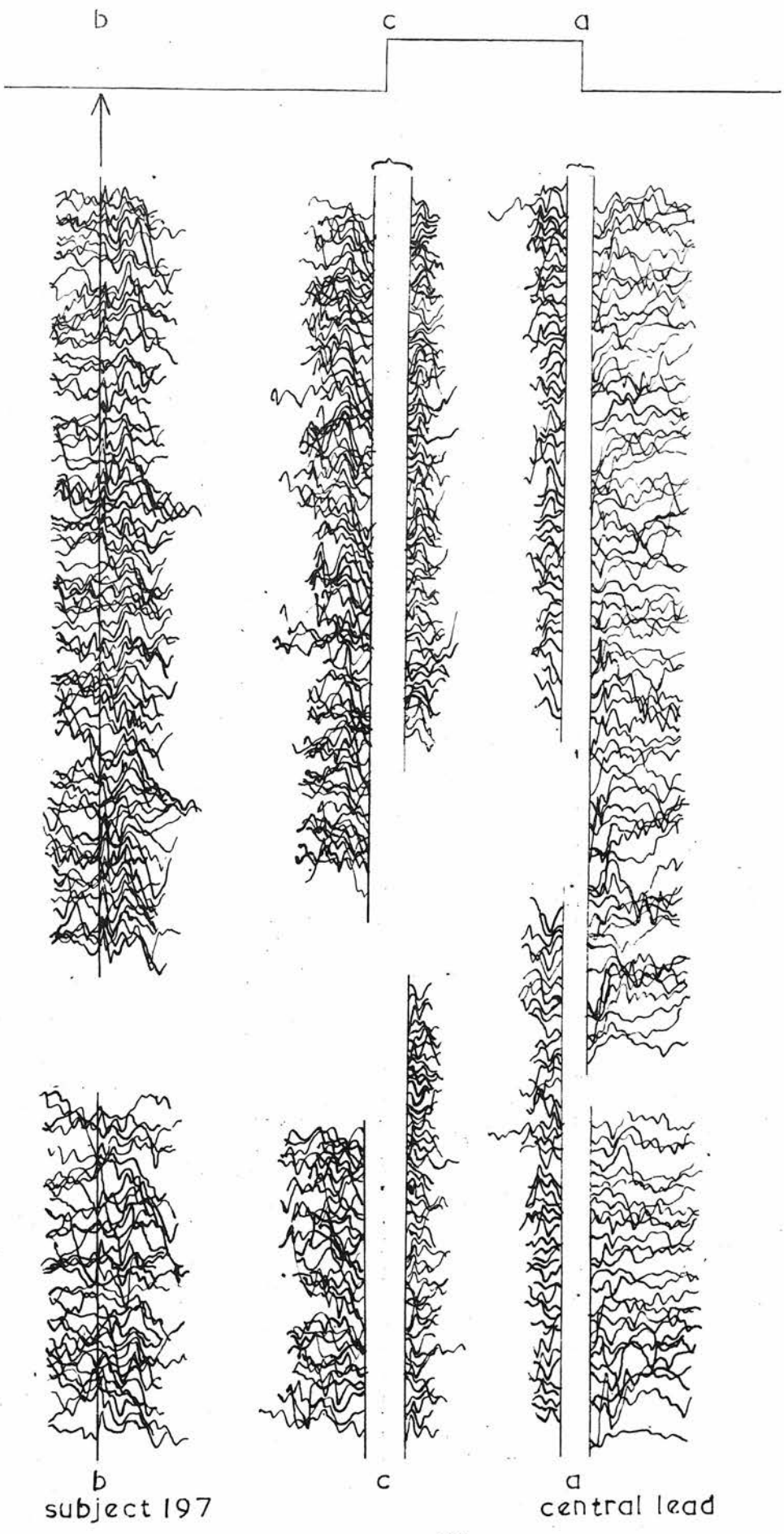


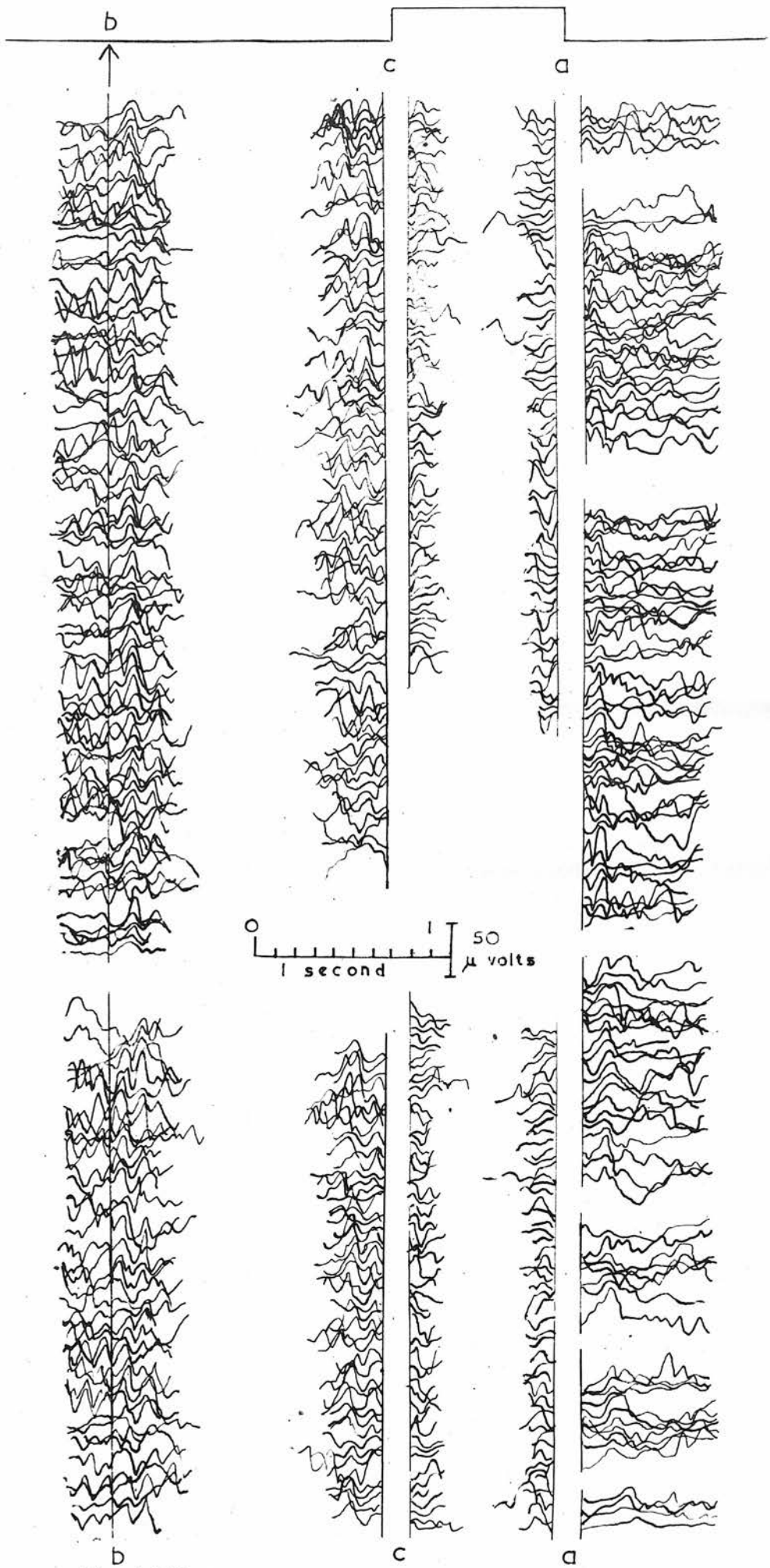
FIGURE 39.

For each subject, the records were marked at the points b, c and a by lines perpendicular to the direction of motion of the paper. The records of electrical activity were then traced for each part of the reaction using these lines as references. Successive reactions were not superimposed but very nearly so. The results appeared as illustrated in figure 39. Each part of the reaction was treated separately, producing five sets of tracings for each lead.

Results.

It was found that consistent patterns of activity (phase relationships) could be demonstrated, associated with a stimulus and the various parts of the response. The pattern was not unique, Where a wave form appeared, its inverse i.e. a wave form 180° out of phase, also appeared consistently. This was found in all records. The proportions of the two varied from subject to subject. (One exception is the occipital lead after line a (repressing the key) e.g. figure 40. In this case, since no consistent pattern was found, the records have been grouped according to the peak of the first wave after a.)

In figures 39 and 40, the signal - noise ratio is seen to be very low. The method of presentation, however, demonstrates the consistencies refered to fairly well. (By viewing the figures at a small angle to the surface of the paper, the effect can be seen more clearly. The results have been summarised in table 3 (10 milliseconds is represented by 0.3 millimeter of record and is the limit of measuring accuracy.)



subject 197

FIGURE 40

occipital lead

TABLE 3.

Position	Waveform	Starts	Stops	Duration	Maxima & Min
Central lead. (after line b)	diphasic	40	160	120	70 & 120
Central lead. (before line c)	monophasic	170	70	100	120
Central lead. (after line c)	monophasic	20	70	50	45
Central lead. (before line a)	monophasic	100	20	80	60
Central lead. (after line a)	monophasic	60	130	70	100
Occipital lead (after line b)	diphasic or triphasic	40	140 or 190	100 or 150	65 & 115 (& 140)
Occipital lead (before line c)	monophasic	170	70	100	120
Occipital lead (after line c)	monophasic	20	90	70	55
Occipital lead (before line a)	monophasic	100	20	80	60
Occipital lead (after line a)	monophasic peaks at	30, 50, 70, 110, 130, 160 & 200			

Consistent patterns associated with stimulus and response

(Average times in milliseconds, taken from the position reference.)

With the exception of the wave form after line a, all waves occurred over times which are significant in altering the organising times Δ. (Two responses were not given to two stimuli separated by less than 175 milliseconds). They can be related, by coincidence, from the above results, but difficulties arise owing to the presence of the inverse patterns. The presence of the inverse probably indicates that the patterns observed are at least one step removed from the 'action potentials'. An alternative may be to consider that 'potential gradient' is the important aspect of the waves. It would, however, be dangerous to claim

anything more than coincidence. It will be seen from figures 36a and 37b, that a change over from long to short △ coincides, approximately, with the time at which a peak (or trough in the inverse) occurs, before and after line c, and before line a. After line a, a peak in the central record occurs at a time when b2 c2 - RT is shorter, than at moments earlier and later. The occipital record cannot be compared since it shows no consistent pattern after line a.

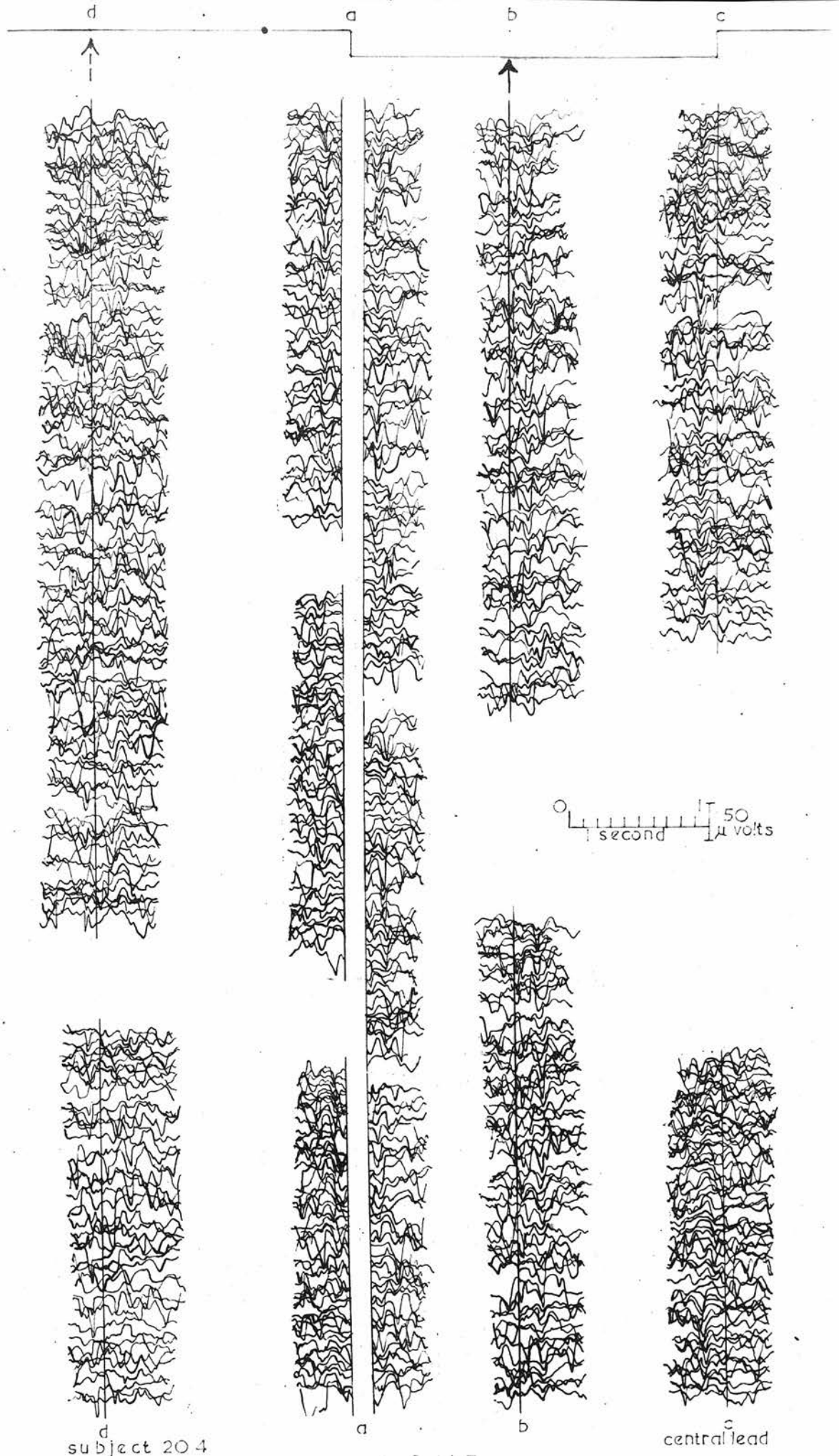
In Summary, consistent features of the electroencephalograms between stimulus and response have been demonstrated. It has not been possible to relate these features to the variations in organisation time, to a second stimulus arriving at a similar phase of the reaction. It is hoped that with more refined techniques of recording and analysis, as for instance those of Dawson 1947, 1950, 1951 and 1954 i.e. photographic, statistical or electrical, that some aspects of these consistent features will be shown to relate to the reaction more than by coincidence of time.

CHAPTER 13

EXPERIMENT FIVE.

Part of the central organisation may be accomplished during a preparatory interval. This has been examined in the fifth exploratory experiment.

Electroencephalographic recordings were made during a choice reaction time experiment. The subject was shown a small, very dim green light (1 candelas) as a signal to press the key; this was followed, between 0.5 and 2 seconds later, by the usual high intensity white light from both sides of a partitioned lantern, to which the


d
a
b
c
second
50
μ volts
d
a
b
c
central lead
subject 20 4

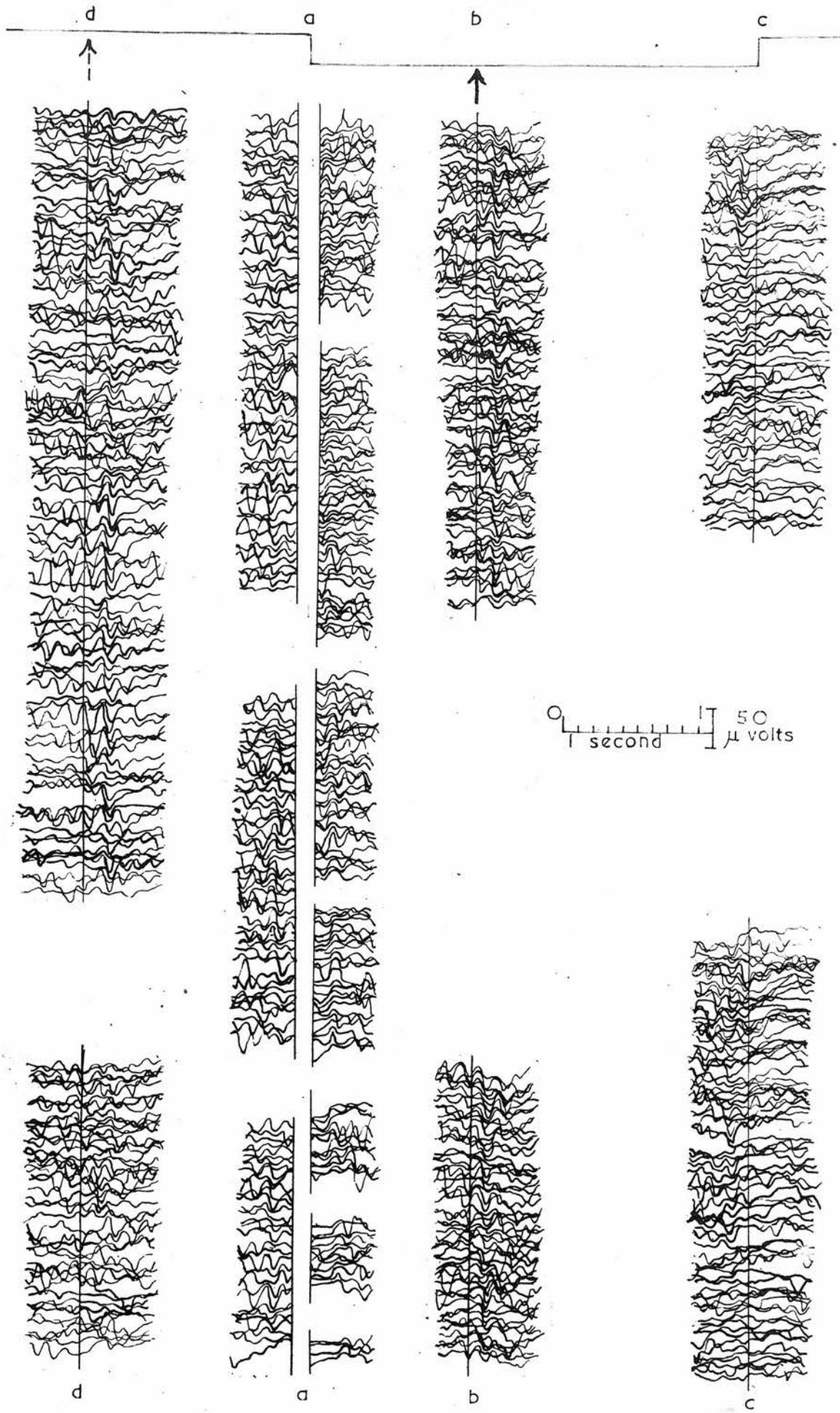
subject responded as quickly as possible. The subject was instructed that if one side of the lantern only was illuminated, then he was not to respond (in the usual manner by releasing his finger from the key), but to wait until the light was extinguished, 3 seconds later. Thus, it was hoped to examine the effect of a preparatory signal, together with the inhibition or dissipation of the organisation from the reactions to which the subject did not respond.

Usually, between one hundred and fifty and two hundred stimuli were given in which the 'trick' signal occurred on ten per cent of the occasions, in a random manner (the total number of trials depended upon the time available for testing the particular subject, usually forty minutes after fixing the electrodes etc.) Simultaneous records of the occipital and central activity were made throughout the experiment. The record was marked at the onset of the preparatory signal, the preparatory response, the stimulus and the response. Lines were drawn perpendicular to the motion of the paper at these points, and the records analysed for consistent patterns in the electral activity associated with the phases of the reaction.

Results.

It was found that consistencies in the phase of the activity could be identified following the preparetory signal, and throughout the reaction, with the exception of the occipital lead after the preparatory response of pressing the key line a. Figures 41 and 42 illustrate the results.

In this experiment, as in the last, where a



subject 204

FIGURE 42.

occipital lead

particular pattern occurred, so also did its inverse. The preparatory response produced a special case; three consistent phase groups were identifiable before and after line a in the central activity and before line a in the occipital record. This was common to all subjects tested.

Table 4 summarises the results as before.

Table 4.

Consistent patterns associated with stimulus and response

Average times taken from reference position. (milliseconds)

Position		Waveform	Starts	Stops	Duration	Maxima or/ and Minima
central lead	after line d(i)	monophasic (mostly)	150	230	80	190
	(ii)	monophasic	150	230	80	190
	before line a(i)	monophasic	160	70	90	115
	(ii)	monophasic	180	100	80	140
	(iii)	monophasic	180	70	110	130
	after line a(i)	monophasic	50	160	110	100
	(ii)	diphasic (mostly)	30	170	140	85 & 130
	(iii)	monophasic	70	170	100	120
	after line b(i)	diphasic	100	200	100	130 & 180
	(ii)	diphasic	100	200	100	130 & 180
	before line c(i)	diphasic	160	20	140	110 & 60
	(ii)	diphasic	160	20	140	110 & 60
occipital lead	after line d(i)	diphasic	100	230	130	140 & 180
	(ii)	diphasic	100	230	130	140 & 180
	before line a(i)	diphasic	190	50	140	150 & 100
	(ii)	diphasic	190	50	140	140 & 90
	(iii)	diphasic	210	70	140	170 & 125
	after line a	first peak occurs at 40, 75, 110, 135 150, 180 and 230				
	after line b(i)	triphasic	60	170	230	90, 140 & 190
	(ii)	triphasic	10	190	200	40, 110 & 170
	before line c(i)	monophasic	110	80	30	70
	(ii)	monophasic	150	100	50	100

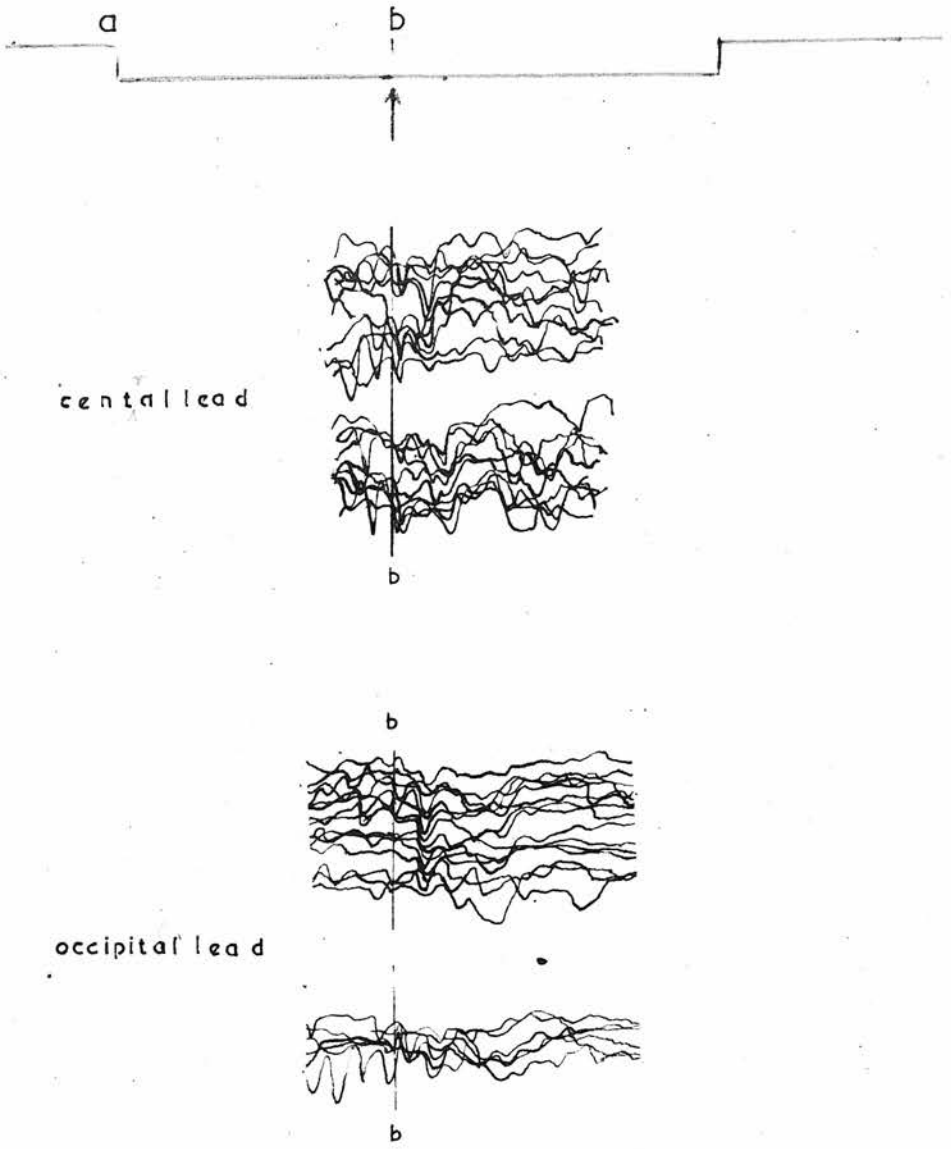


FIGURE 43
subject 204

The estimated positions of the patterns were averaged over twenty subjects, but the possible error of the estimations is liable to be very large. These results are intended to indicate the approximate positions of the patterns. Quantitive methods as mentioned, will be necessary for more exact localisation.

It would appear, however, that consistent patterns of the electrical activity of the cortex are associated with the preparetory phase, as well as the stimulus and response. The exception of the occipital activity after pressing the key (line a), is again noticeable in this experiment. It was expected that the pattern following the stimulus, would follow the line b with less time lag, in this experiment compared with the last. However the lag is found to be greater. It may be tentatively concluded, that this increase is associated with the 'choice' aspects of the perception necessary in this experiment.

The activity, following a stimulus calling for an inhibition of the responses, showed no significant difference from the above. The records of these reactions, for which only one half of the 'lantern' was illuminated, were treated in the same manner, and the presence of the characteristic wave forms was detected as illustrated in figure 43. The record of subject 204 was used for this illustration, as for figures 41 and 42. By comparing the two, no difference has been found. It is perhaps significant, that the proportions of the central records, in each of the two groups, is different from the proportions in the two groups from the occipital

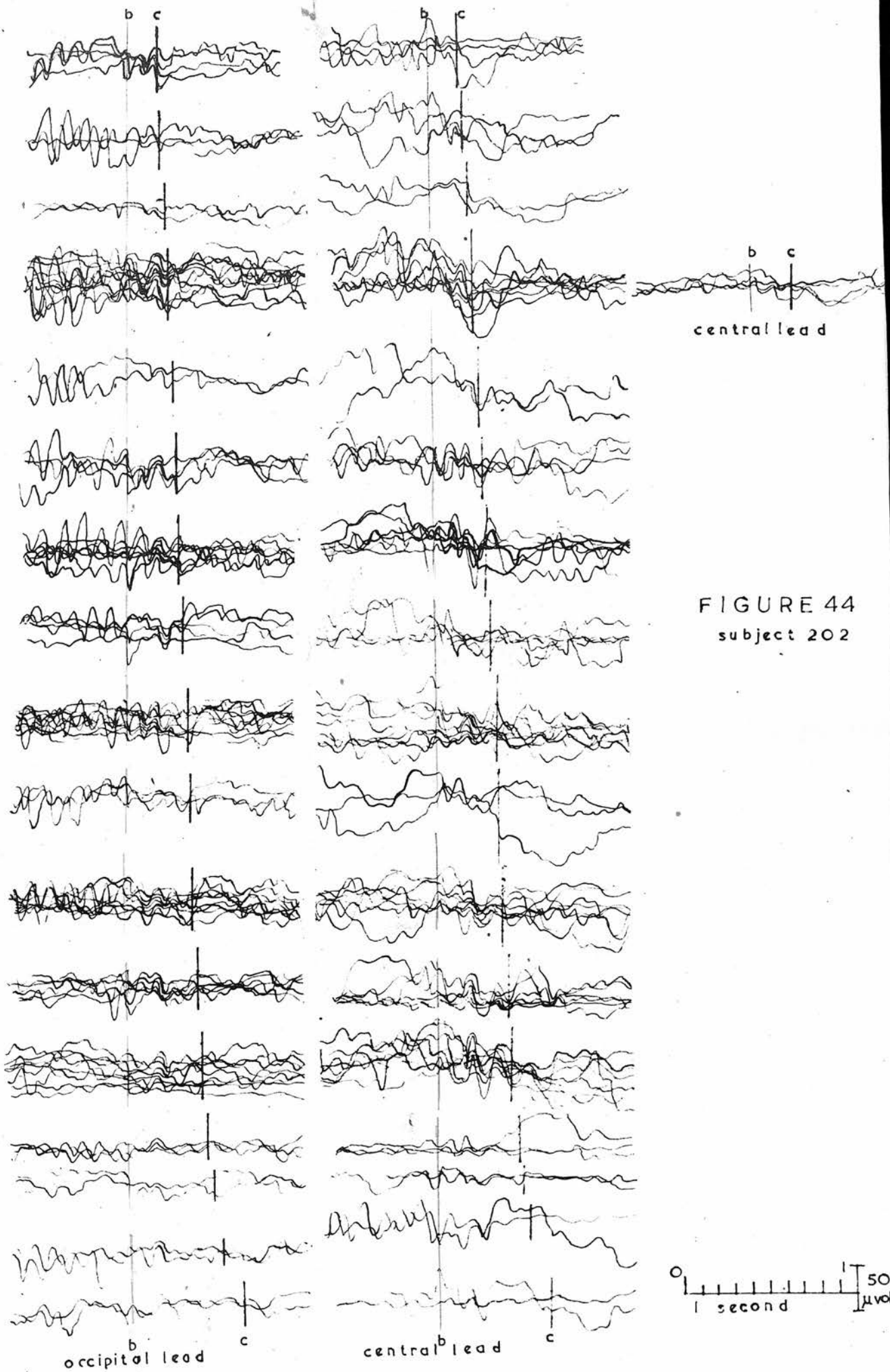


FIGURE 44
subject 202

region.

In the course of the examination of records, (as figure 41), it was noticed, that reactions of the same length usually fell into the same group and, on closer inspection, other similarities appeared. As a result, reactions were sorted by reaction time, and the activity between stimulus and response (b c) in both leads, was examined. This was done in the usual manner by tracing, and as a result the high noise level is very much in evidence. In figures 44 and 45 this phenoma is illustrated with the records of two subjects.

1. Activity is seen to be consistent for any given length of reaction, in each lead.

2. The more reactions in a group, the more apparent the pattern becomes; illustrating the validity of the conclusion, and the 'randomness' of the 'noise'.

3. In grouping the records by the length of reaction, it appeared that the reaction times were of a series of discrete lengths. This, though making the task easier, raises some important problems. The time difference between each group was on the average 10 milliseconds, representing a clear difference when the records are superimposed but within the possible variability of paper speed. It might, therefore, be expected, that responses from one group, would be found in the adjacent ones.

4. With subject 210 figure 45, this was most noticable. Reactions not conforming to the particular pattern of a group were traced separately, and are illustrated alongside that group.

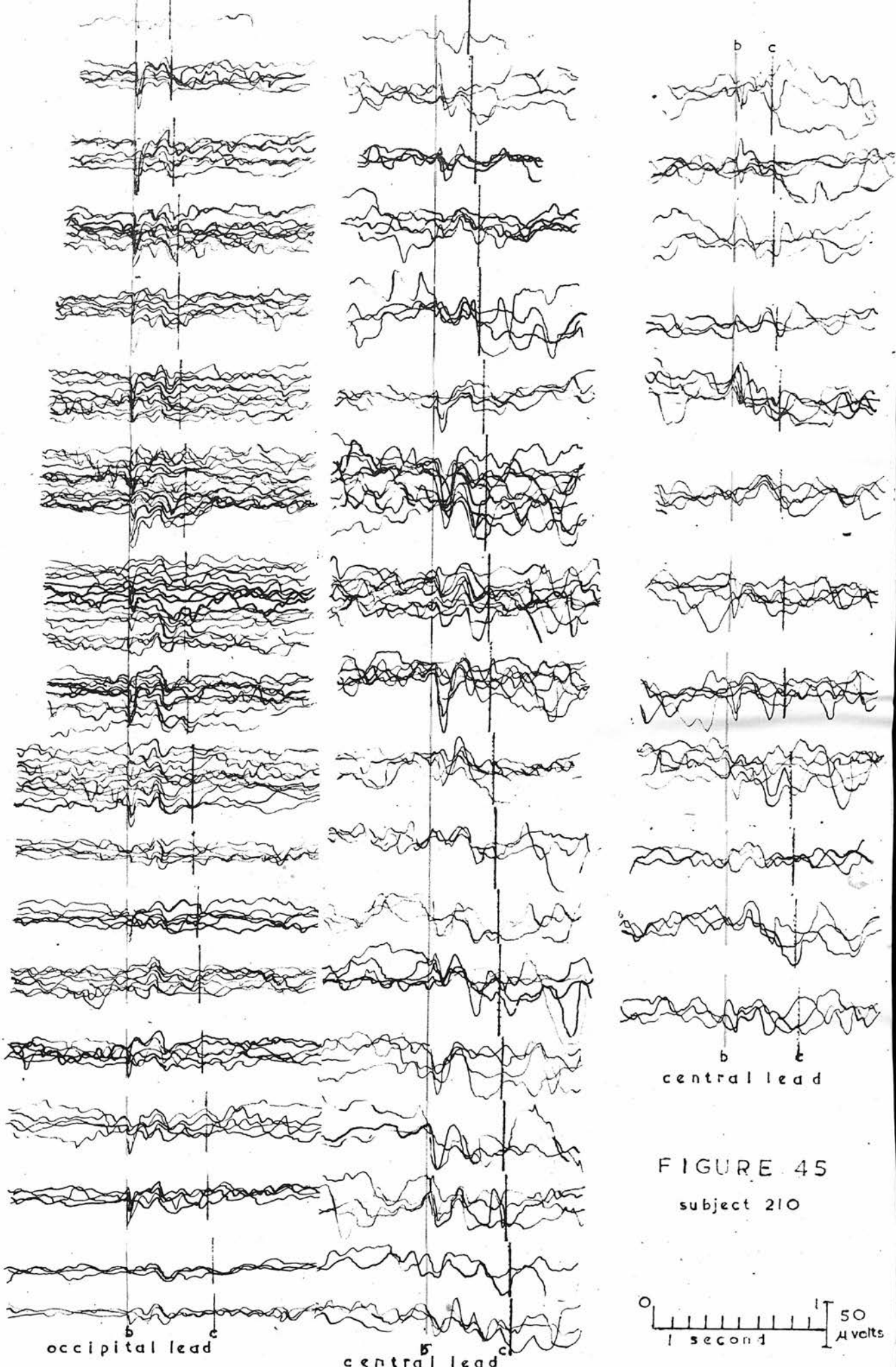


FIGURE 45

subject 210

(There is also indication that the reaction times were slightly different from the main group). Examination of the pattern, seen in the central record in these atypical types, indicates that they should belong to one of the adjacent groups. The likelihood, that the brain is more accurate than the apparatus, is very high. Patterns from the occipital leads show relatively little change, from group to group, in most subjects, and for this reason, all patterns for each group were included together. Fortunately, the paper speed varied less with other subjects than with subject 210, and the results are less equivocal.

The implications, of the demonstration of consistent patterns of the cerebral activity for any given reaction time, are important. It can be argued, from this result, that the cortex must go through a similar series of changes, before a response of a given latency Since the stimulus was the same at all times, it follows that the brain must have been in a similar state of readiness at the occurrence, of each of the stimuli for each group. If this state is described as sensory organisation or expectancy, the reaction time can be said to represent the state of expectancy at the on-set of the stimulus.

(Experiments, which are at present in progress but lie outside the scope of this paper, extend this result. Three reaction time experiements are carried out with each subject, prepared with simultaneous electroencephalographic recording, viz, a single choice simple reaction, a two choice (two lights and two buttons to be pressed) and a three choice reaction time experiment (three lights and three buttons).

The patterns are assessed quantitatively (Dawson 1954), and averaged for each subject. It has been found, with two subjects to date, that where reactions are of the same length from a subject, whichever experiement (or stimulus), the pattern is similar).

Summary. Consistent, but not unique, patterns of electrical activity, recorded from the scalp, have been shown to be associated with the various fixed points of a stimulus, and its response. It has not been possible to relate these patterns to variations in the organising time to stimulus, due to the nearness of the previous stimulus and response. Welford's results, on the way an organising time is held over, have been substantiated and extended for occasions when the second stimulus arrives before the completion of the previous response. Welford's theory and the present results are not in agreement, when the second stimulus arrives after the end of the first response.

The electrical activity, occurring in the course of a prepared choice reaction, has been examined and shown to be consistently associated with the various parts of the reaction, to the same degree as the above. No difference was recognised during the inhibition of a response when compared with the above.

Electrical activity between stimulus and response, has been shown to be similar for each group of reactions, from a subject, which are of a similar length. Differences between the records of different subjects have not been explored.

SECTION FIVE

CHAPTER 15.

The Time of Perception.

The factors affecting the time of perception have been discussed, and conclusions have been reached as to the nature of the mechanisms which are necessary and sufficient to account for the experimental data. The discussion was of greater length than minimally necessary, because of the importance to psychology. For instance, attention - secondary motivation - is recognised as the most important motivational factor in human learning, so much more than the primary motivations, that writers have wondered whether the latter play any part at all.

If the human operator is said to have an expectancy, he might be described as predicting the future with a certain degree of probability (or uncertainty). The higher the probability the more 'frustrated' he will be, if the expected occurrence does not materialise for any given degree of motivation. He can 'extrapolate' into the future, on the basis of consistent occurrences in his past (learning) or immediate past (expectancy). By definition, any consistent occurrences can be defined mathematically, either logically, if the number of independent variables is small, or statistically if they are great in number. The organism builds up an equation in the process of experiencing, in terms of causality, not only in direction, but also including time relationships. In order that extrapolation can take place, the subjective equation must be solved by the subject in terms of a positive time variable, i.e. the future.

Many attemtps at quantification in psychology, in terms of logical or statistical formulae, have been made. As ends in themselves, they are little more than intellectual toys, but quantification, in terms of a mathematical equation, can have great value by precisely and concisely conveying a great deal of meaning. The formal relationships between variables in learning and in certain variables in society, have been set out by Rashevsky (1931, 1947) and extended by others in the Department of Mathematical Biophysics at Chicago. The main difficulty with this work is that the variables chosen are not necessarily fundamental, and do not lend themselves to quantification, owing to the fact that in many cases they can not be isolated, or if so, are vectors in a multi-dimensional universe to which no scaler values can be assigned. Without proof of their existence, further discussion would be fruitless. Two other forms of quantification have been suggested. Laplan (1950) and McCulloch and Pitts (1943), apply the technique of Boolian Algebra to various forms of behaviour, and the discussion is very much the same as the applications of topological geometry to psychology by the Lewinian school, Lewin (1936, 1940, 1942). By definition, arithmetic quantification is excluded from the final system. In contrast, the work of Hull and his associates (1943, 1947a 1947b, etc.,) in which the relational formulations are very strictly deductive from a series of relatively few postulates, and much experimental evidence stands as a "programmatic" (Hull 1947b, p.517) study of factual material with suggested fitted equations.

The development of another method has occurred as a result of certain similarities between complicated electronic devices, that may solve problems, attain goals, etc., well and efficiently, and the human. In dealing with these devices, it is possible, given a certain input, to predict the output, with limited knowledge of the machine. The treatment of the human, as one example of such a machine, is the approach suggested by cybernetics.

This is no more or less than that which Hull (1943) explicitly stated is the purpose of 'Behaviour Science'. Indeed, Hull was one of the prime movers, at the time when the scientific psychologist was just realising the analogy between his subject matter and modern electronic devices and concepts (c.f. Kubie 1930). Hull's model, showing all the characteristics of conditioning, is still perhaps the best and most simple of its kind (1931b).

The subject matter has fallen into two compartments: servotheory, the theory of the unit, and communication theory, the theory of transmission between units, however complicated, or simple, the unit or the channels of transmission may be. The principles of servotheory are not descriptive of particular mechanisms, but generalisations of certain types of goal-getting behaviour. It is true, however, that the methematicians, and so on, who developed these principles, have done so with reference to the machine, but by definition, they must hold for all mechanisms capable of goal-directed behaviour.

The nature of the subjective equation.

This may be considered, using the concepts of communication theory.

As Mackay (1951) has pointed out, all information depends upon the presence of a set of constructs, but in communications, it is found more useful to limit these constructs to a number of *a priori* possibilities from which the signal selects. For example, choosing a particular file from a filing cabinet, or sending a code number referring to one of a limited number of greetings telegrams. It does not, therefore, in this system, refer to the semantics, although the same constructs may be applied to problems of meaning (Mackay loc.cit.)

The theorem of Shannon (1949) and its application to the reaction time problem by Hick (1952), are now too well known to need more than a short introduction.

Communication is essentially a matter of stimulus and response. We should be able to treat any problem, and in particular, the reaction time, in such a way as to be able to measure the rate of gain of a given amount-of-information.

Hick has shown (1952), by a repetition and extension of an experiment by Merkel (1885), that the value of 'choice' reaction times, when plotted against the number of alternative stimuli possible, appeared to be close to a smooth logarithmic curve, such that for any number of alternatives N, the reaction time was equal to K $\log_2$ N (Hick included the state of no stimulus as subjectively equally probable). The average rate of gain of information, he found to be 5.6 bits per

second. If this is thought of in terms of a simple reaction time experiment where the light may at any time be on or off, i.e., the information would be one bit, the predicted reaction time should be 0.18 second. This is remarkably close to the average reaction time with preparatory signal, found by most experimenters (see Woodworth (1938). (Hick's subjects were told that the frequency of each stimulus was the same, but the selection was random).

Communication theory treats the human as an approximately linear element in a chain. The main property of a linear element (transducer), is that the constants shall not change with time.

Just such a change in constructs is being considered in this paper. Set and learning are the properties which make the above approximation unreliable. If an unprepared stimulus arrives and the subject has been told that it <u>may</u> arrive, the reaction time would be about .3 second, on the average. If the subject had not been warned that it may occur, or if a preparatory signal had been given (i.e. the expectancy changed), the reaction time would, on the average, be much greater and much less respectively. This is equivalent to building two completely new communication channels with different characteristics.

It is suggested that these "new" channels may be compared with the "old", by considering that the amount of information transmitted (in communication terms) by the

human, has varied (as it certainly has in the semantic sense). Whilst the rate of transmission has remained constant. If the characteristics of the source have not altered, change in expectancy is equivalent to changing the connections between the source and the transducer.

In Hick's experiments, extended practice was given running into thousands of trials, the expectancy (the probability to the subject of the stimulus occurring, or more shortly, the subjective probability) and the objective probability were most likely to be constant, and approximately equal, on the average. Therefore, it is reasonable to assume from the results, that the rate of amount of information is constant. Provided that the subjective probability (expectancy) remains constant, the subject reacts with an average latency determined by the average probability of occurrence of the stimulus. If the subjective probability changed, then the response latency changed; if the rate of gain of information is assumed constant, the amount of information gained from the occurrence of stimulus must change, and it will do so in proportion to the subjective probability.

Since subjective probability may be inferred from the reaction latency, its relationship to any immediately preceding objective state of affairs may be determined.

Subjective probability will be a quantity derived from the experimental results and bearing no relation to any mentalistic concepts or introspection. It is, in a sense, a way of pointing out that the representation of the external world in the brain is not by means of a mirror, but is

relative to the previous representations (past experiences) and the ingoing stimuli (present experience).

An Alternative approach.

Cherry (1955) has stated, that communication theory must be applied to the human from the viewpoint of an external observer. The rate of gain of information is computed by an external observer who "sees", both the source i.e., the actual probabilities of the stimuli, and the output of the human operator. The rate of gain of information is thus "entirely in terms of the complete probability distributions (averaged at that)" (sic). Communication theory is not expressed in the language of the participant observer who can only describe the source from his received (possibly noisy) signals.

The total perceptual mechanisms of a human operator may be regarded as a number of filters, all of which have to be scanned for the relevent information.

Increase of expectancy of one stimulus, or stimulus complex, may be said to reduce the expectancy of others, perhaps by reduction in the facilitation of the associated organisations (i.e. attention is focussed). Thus, the time taken to scan and hence the response time is reduced, also the band width (the subjects horizon) is narrowed.

Stimuli and central processes, which are to some extent irrelevant to the task in hand, are excluded, and it can be said that the "noise level" is reduced. The rate of information transmission is defined by Shannon (1949), as the difference between the signal entropy and the noise

entropy. So, for a reduction in noise, a source with given characteristics and a constant rate of transmittion, more information can be transmitted in a given time i.e. the reaction time to the signal is reduced.

The noise level (irrelevent stimuli and central processes), may be regarded as modifying the characteristics of the source. For instance, though the source probability of a stimulus may be high, if the noise is also high, the transmittion time is long. The latency, which may be of length x, is equivalent to transmitting a signal of lower probability, say P_1, at the same rate. With a change in expectancy, the equivalent probability may become P_2, and the expectancy change can be referred to as $P_2 - P_1$. This equivalent probability can conveniently be called subjective probability to differentiate it from the source characteristics.

The concept of subjective probability may be broadened considerably to include a wide variety of phenomena without invalidating the foregoing. With certain reservations, in order that the living organism may be capable of adapting to the environment, the subjective probability and the objective state of affairs should approach equality.

The recent research, directed by Cantril (Kilpatrick 1952), attempts to delimit certain of these reservations in relationship to the anomalies which may occur in the recognition of perceptual phenomena. The fundamental point with which they set out, ~~work~~ departs from previous perceptual theories in that they reason from the physiological stimulus pattern

to a related external configuration. It is clear from this approach, that there will be no invariant relationship between the two. In visual perception, any given stimulus pattern can be produced by an infinity of different external conditions. Under these conditions, an illusion becomes one of the matrix of alternative sets of cues which give rise to the perception in question, provided that the perceiving organism makes an assumption about the nature of the external conditions, based upon the cues. Assumption is the word used to depict the effect of past experience, and it is described as 'unconscious'. In the past, the word expectancy has been used for the same phenomenon, and, in terms of the rationale given above, we may say that the interpretation of the cues, resulting in a particular perception, is due to the fact that the subjective probability, that the cues represent the external condition associated with the perception, was high. Kilpatrick comes to exactly the same conclusion (p89)

> "By perception, then, is meant that part of the transactional process which is an implicit awareness of the probable significance for action of present impingements from the environment, based on assumptions related to the same or similar impingements from the environment. By assumption is meant that generally, unconscious aspect of the transactional process which may be described as a weighted average of past experience in dealing with those portions of the environment to which it is related. Assumptions function as probabilities which are built up by action, checked by action and modified by action ..."

The 'assumption' as described, appears to be the facilitation of the cell assembly representing the whole

from incomplete data in Hebbs terminology. Hebb talks of the interfacilitation of b and c from assembly a and of a and c the whole will also be facilitated in the same way as a result of the sensory facilitation of a, b, c, etc.; a perception of the whole is then possible. It could happen (as Hebb points out p.103) only with a simple and thoroughly familiar figure and this agrees with the experimental facts. The experimenters Kilpatrick and his associates use representations of rooms, walls, windowframes, and so on in the demonstration of the phenomena. Hebb (p.93) when describing the 'spacial hypothesis', quotes experiments that learning in the rat was governed, in the absence of any direction as to which cue to take, by a spatial orientation to the background such that it was dominant over other more direct cues. He concludes that the reason why the position habit is so persistent is "the animal mainly perceives and response to the least variable objects in his environment which are the ones at the greatest distance".

The similarity of the concepts used by Kilpatrick et al and those of Hebb together with those it has been found useful to use in this Paper is very encouraging, as is the fact that such different approaches are yielding comparable constructs.

The amount-of-information and the subjective probability are scalar quantities and would therefore serve as useful measures of the normally intangible properties of a stimulus and allow us to compare with the aid of such

measures, two otherwise vastly different stimuli.

The idea is that expectancy may be treated as a statistical function of the subjects previous experience. This it will be possible to assess, on the basis of the method as described, in terms of subjective probabilities. These can be directly compared with the objective situation. It seems most likely that, at the first approximation, these two will be equal i.e., subjective probability will equal the preceding objective criteria.

The possible extensions of this methodology are numerous. In pathology, the patient is typically " out of touch", "not in contact with reality", etc. The subjective probability would show a very marked discrepancy from the objective state of affairs, or in the extreme, we may find that the subjective equation is insoluble in reality for the patient, since it would be built up more in terms of some internal condition than the external situation.

Most symbolic behaviour implies coding (verbal, visual, etc., formulations). In projection tests, where decoding is invited by the experimenter, a series of responses are obtained which can be clearly assessed in terms of their cultural or everyday probability (e.g. common versus uncommon responses on the Roscharch test). The object of such an assessment is to, factually and quantitatively, compare the two or more types of material (i.e., stimuli, etc.) in relationship to the individual. Where memory and recall play a part, their time characteristics must also be estimated before a quantitive estimation of rate

of output of information, can be made.

Here also, is a basis for the definition of unit time of perception. Provisionally, it may be described as the time for gain of unit information, thus paying implicit attention to 'expectancy'.

Normally, the range of values of the reaction time is relatively large. Hicks value is the average from a wide range of results. Very often it is desired to refer to the result for a single reaction, or a number of reactions chosen, according to some non-random law, from the distribution of results. From the viewpoint of Communication Theory, it would not be admissable to deduce the probability of the source from such data. From the results of experiment five, it seems that the sensory organisation, at the onset of the stimulus, can be inferred from the reaction latency and consequently, it may be legitimate to assess the subjective probability in discrete reactions, as common experience would predict.

One important aspect of expectancy is stressed by this theory. Gain of expectancy (sensory organisation) is accompanied by reduction in attention to the rest of the environment.

Serial variations, in the reaction times observed in three of the experiements, have been examined to provide illustrations of this concept. In experiments one (twelve second interval), four and five, the normal course of the reaction series was punctuated by "trick stimuli" (non-

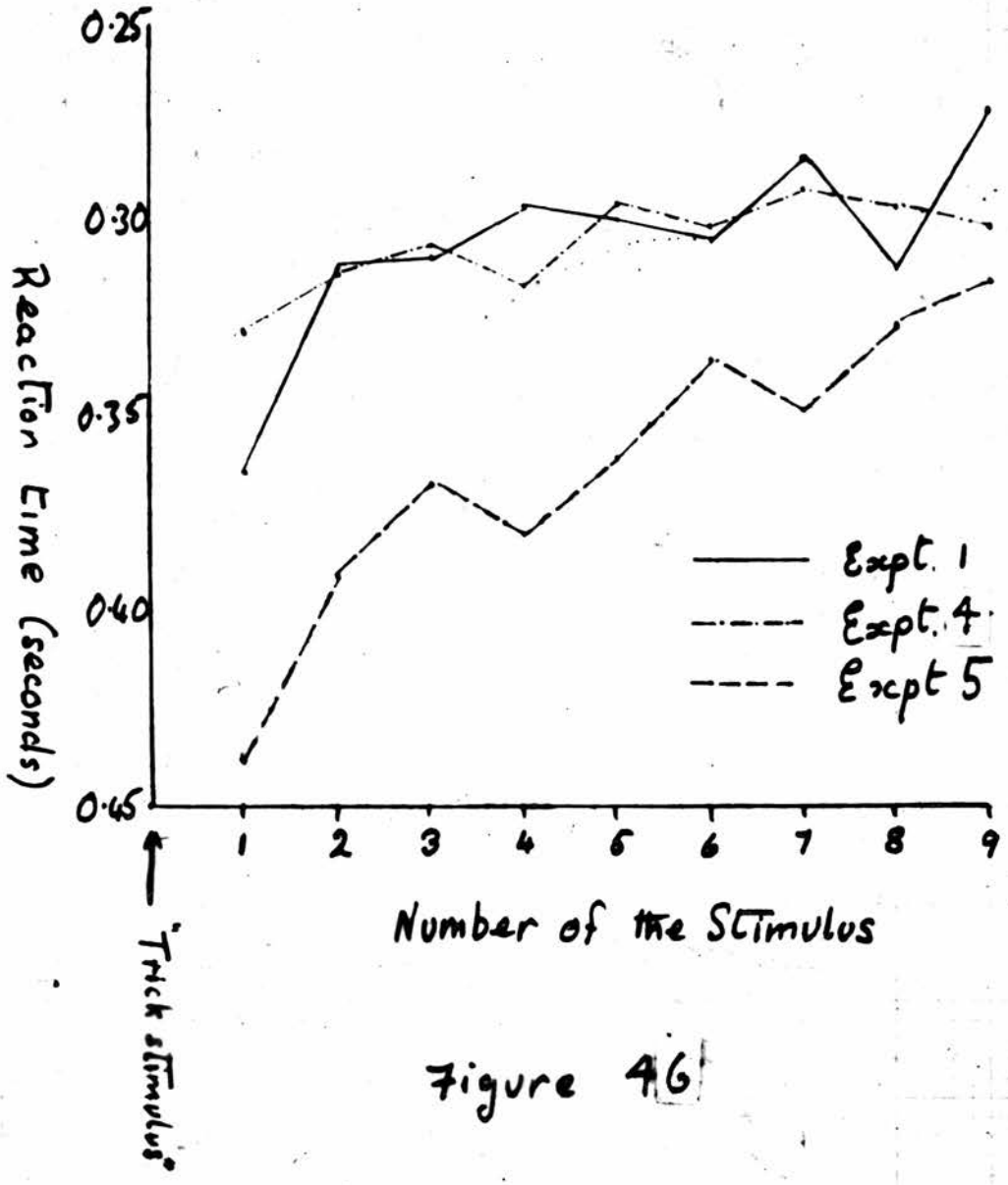

0·25
0·30
0·35
0·40
0·45
Reaction time (seconds)
1
2
3
4
5
6
7
8
9
Number of the Stimulus
Trick stimulus
Expt. 1
Expt. 4
Expt 5

Figure 46

standard intervals, a second stimulus arriving during the course of the previous response, or by a similar stimulus which has not to be responded to following the usual preparatory signal, respectively).

In figure 46, the mean reaction times to each of the series of stimuli, following the "trick stimuli", are shown. The number refers to the position in the series following the trick stimulus.

The effect in experiments one and four is significant but small, compared with experiment five. This may be expected, if the prediction of the next "trick signal" is more important to the subject in experiment five. In experiments one and four, no change in behaviour is asked of the subject by a trick stimulus. The usual response is used in slightly unusual circumstances. In experiment five, the trick signal carries the semantic information, "do not release the key until this is extinguished". Since the subject is primed by the preparatory signal to be ready to respond as soon as possible after a very similar signal (a light of twice the intensity), it may be concluded that the importance of the prediction is higher than in the other two experiments. An accurate prediction of "no trick stimulus", means that the subject can do as instructed i.e., respond to the light as quickly as possible.

The illustration shows that the immediately preceding state of affairs is very important in the formation of the subjective probability, and the effect of the trick stimulus is progressively less at it becomes history. In

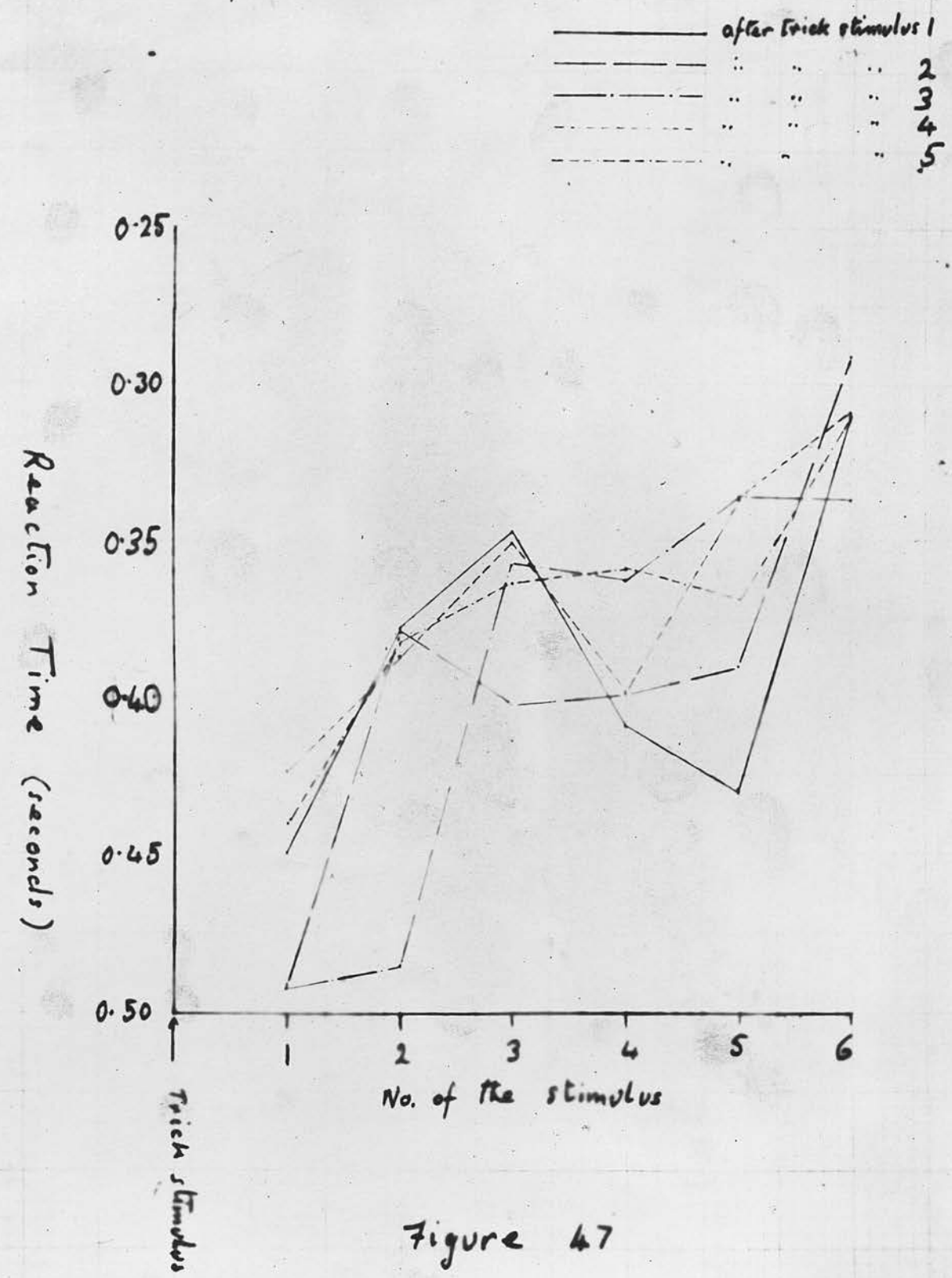

after trick stimulus 1
" " " 2
" " " 3
" " " 4
" " " 5
0·25
0·30
0·35
0·40
0·45
0·50
Reaction Time (seconds)
1
2
3
4
5
6
No. of the stimulus
Trick stimulus

Figure 47

figure 47, the average reaction times to stimuli following the first five "trick stimuli", have been shown. The expectancy of a trick stimulus is seen to drop in the first three stimuli, reach a plateau from three to five and then fall further on the sixth.

The focus of the experimental method in these experiments was not directed towards the reaction times, and the absolute values are larger than in similar experiments, in which the subject did not have to recline on a couch and keep still, or nearly so, for half, to threequarters of an hour. The discomfort so caused, together with that of the "head-dress" holding the electrodes, removed the experiments from the class of "good conditions for reaction time measurement."

However, the relative values of the reaction times, after the "trick stimuli", reliably illustrate the theory. The results, following five trick stimuli only, were shown for reasons of clarity. Figure 48, shows the results plotted to illustrate the effect on reactions following them, as a function of the first ten trick stimuli. The results for the first and second, third and fourth and fifth and sixth stimuli, after each trick stimulus, have been averaged so as to make the figure as clear as possible. It is seen that the third and the sixth 'trick' stimuli have the most and the least effect on the first pair of stimuli following them. The curve is approximately sinusoidal. The fifth and sixth pair are affected oppositely i.e., the third and sixth "trick" stimuli have least and most effect respectively;

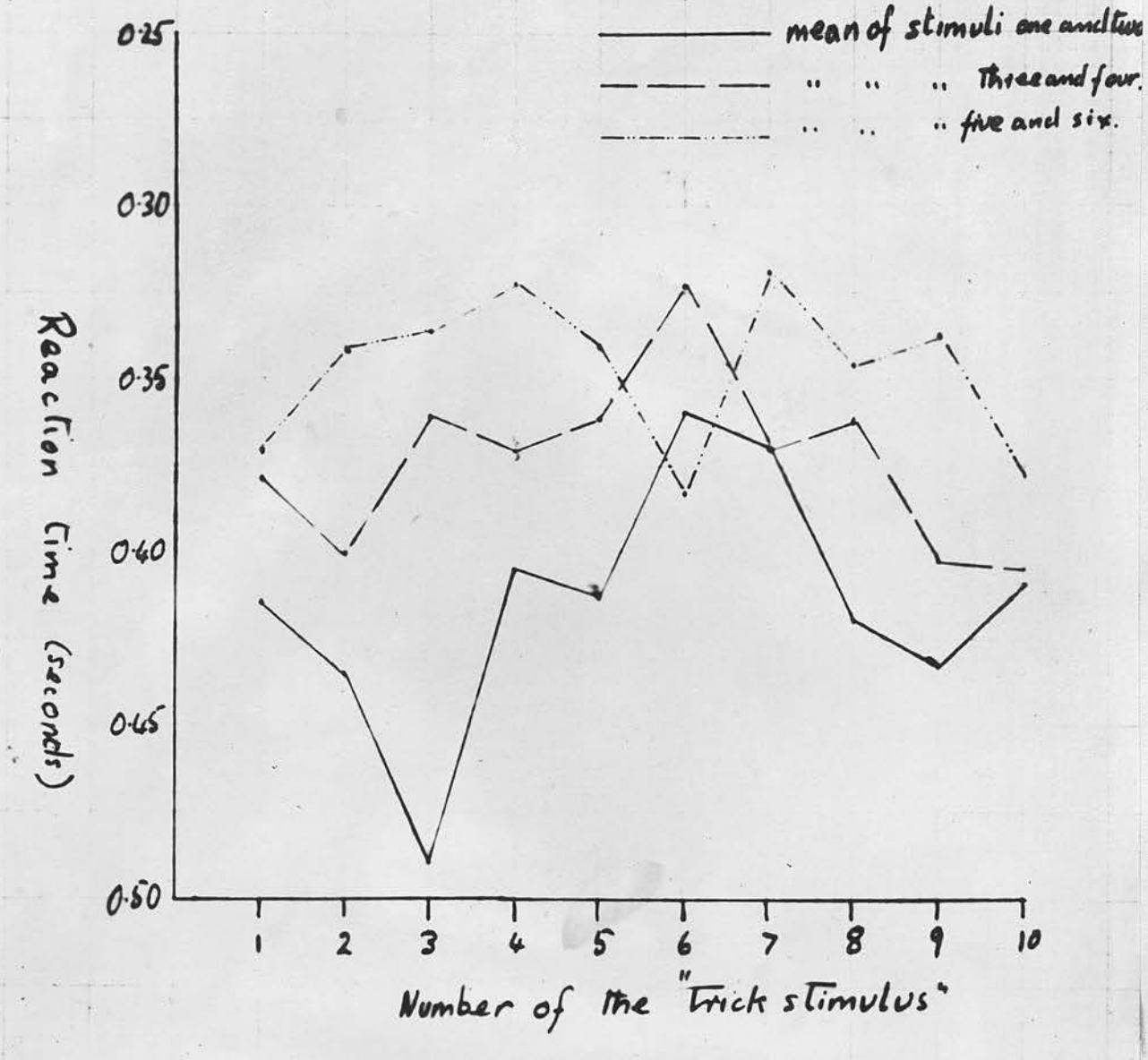

mean of stimuli one and two
.. .. .. three and four.
.. .. .. five and six.
0·25
0·30
0·35
0·40
0·45
0·50
Reaction time (seconds)
1
2
3
4
5
6
7
8
9
10
Number of the "trick stimulus"

Figure 48

and the third and fourth stimuli are affected to a nearly intermediate amount. Possibly two factors are operating, one due to the nearness of the last "trick" stimulus, and one due to the expected proximity of the next; an example of longer term experience. That is to say, if the brain is viewed as a statistical computer, the probability which it assesses the next instant, is based on the immediate past two or three trials, and on something like the average past history of the experiences in the particular situation. The higher the number of trick stimuli, the larger the sample to average, and hence, the more accurate the prediction could be. Empirically, the higher the number of stimuli, the more probable it was that the next one will be a "trick" stimulus.

(I have found it useful to think of the conditions as follows: The brain is 'sampling', with successive stimuli, and this affects the subjective probability, and hence the reaction time decreases. The long term experience of the experiment serves to indicate that trick stimuli may occur, and it gives an approximate frequency. The knowledge of its possible occurrence sets a "zero" (a certain reaction latency). The rate of approach to that value is governed by the average frequency of the 'trick' stimuli i.e., the sampling is suitably weighted.

It is interesting that once the "zero" is approximated to, oscillation seems to start or increases in amplitude, as if a slightly faulty governor were in control.) The time of perception can not be defined irrespectively of expectancy and associated mechanisms, and it will be affected

by all the processes thus far described. It is suggested, therefore, that time of perception should be defined as the time taken for gain of unit information, since it refers to an experimental reality, involving merely stimulus and response on the part of the subject, and implicitly takes into account the role of expectancy, (subjective probability).

The calculation of the subjective probability from the reaction latency will, therefore, involve the antilogarithm of the reciprocal of the reaction latency times a constant (the rate of gain of information which, from Hicks data, = 5.6 bits / sec).

The development of the Subjective Equation.

Craik, whilst in Edinburgh, was one of the first to examine the human as a tracking device. This work he continued in Cambridge and since his death it was taken up and amplified in the Naval Laboratories in the U.S.A. (Stroud), and also by other workers in Cambridge, England. Lately, the work has spread into most of the Biological Science departments and into the applied field.

Craik's theorem (1947, 1948), that the human operator behaves basically as an intermittent correction servo, is fundamental in the field. This theorem refers to the fact that the subject responds to information taken in intermittantly, not that the response itself is intermittant. "There are counteracting processes tending to make the controls seem continuous" (sic): he defines these as inertia (Momentum), and prediction, and says that since the operator is subject to the reaction time lag, he must extrapolate i.e.,

anticipate the physical future. The expectancy of a stimulus after one standard interval, is just this anticipation of the physical future, in Craik's terminology. The essential feature is that the subject must detect the constants in the task.

These constants seem to fall into three groups, position (time), velocity and acceleration. There is evidence (from accommodation of nerve and sensory adaptation). that differentiating systems of the first order, at least, are present in the human, which may serve to measure rates of change of stimuli. (Stroud 1949) reports that when asked to track a function, whether the subject's control is arranged so as to alter the tracking spot by simple displacement, by velocity control or acceleration, or any combination of these three, the operator can succeed, after practice, in keeping within a very close margin of error. In other words, the 'servo-tracker' is solving the first derivative, the second derivative and the original equation, or any combination of these.

Learning and expectancy may be built up in an open chain, without knowledge of results (i.e. conditioning) but the process is slow and relatively easy to extinguish. In a closed loop, where knowledge of results or errors is given, learning is relatively fast and accurate. It is, for instance, impossible to imagine a complex perceptual-motor skill, say typing, to be built up as a result of open chain learning, (where the subject at no time saw the key board, or the typing, or was told anything about it).

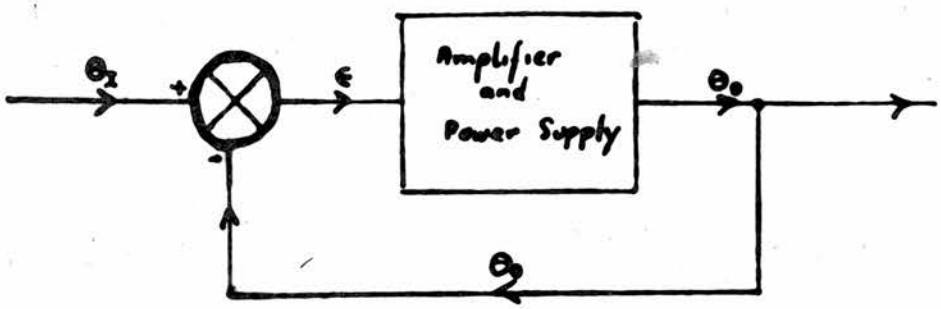


Figure 49a

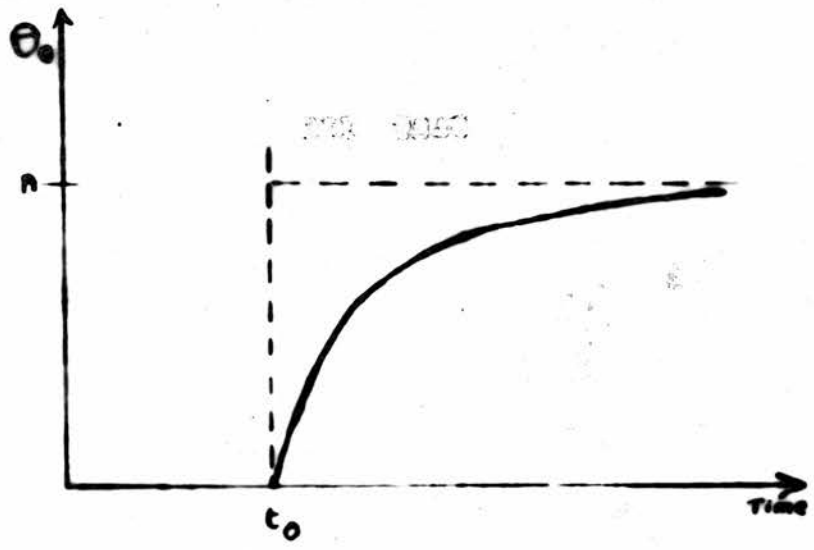


Figure 49b

In figure 49a, is illustrated schematically, the simplest possible closed cycle control system. The output θ_o is subtracted from the input θ_1 to obtain the error signal, ϵ. This error signal controls the motor apparatus, usually via some sort of amplifier. (This is negative feedback).

Such a system can be easily shown to be represented by the equation

$$\frac{d\theta_o}{dt} + K\theta_o = K\theta_1$$

θ_o and θ_1 are the output and input respectively, in the same units, t is time, K is the constant of proportionality or transfer function of the operation of the motor apparatus per unit input of ϵ.

(Further data and proofs can be found in James, et al 1947).

This equation represents the conditions for proportional control. Other types of control change the equation into a higher order, differential equation. Most practical servo-systems are either linear or can be approximated sufficiently closely by a linear representation (Getting 1947).

We normally examine an animal's ability to learn, by imposing a restriction on its need reductions. The reduction must take place under such conditions by the organism undergoing a series of manoeuvres taking time. The input signal can be said to be suddenly stepped to an amount representing this restriction. The animal 'adapts' by learning the maze and so making θ_o approach θ_I, as closely as possible. In examining a servo-system, it is also

standard practice to examine the change of output for a stepped input.

A discontinuous change of input θ_I is applied and usually in the following way: θ_I is zero for all times up to t_o and then suffers a change to a new constant A for all times greater than t_o. Let this step function be applied to the simple servo system described above.

The step function is shown in the figure 49b, as a dotted line, and the response as a full line.

The output approaches the input as the time beyond t_o increases without limit.

The differential equation is (as before)

$$\frac{d\theta_o}{dt} + K\theta_o = K\theta_I$$

and when solved for $\begin{cases} \theta_I = 0 \text{ when } t < t_o \\ \theta_I = A \text{ when } t > t_o \end{cases}$

becomes $\theta_o = A\ (1 - e^{-K(t - t_o)})$

In the case of the development of sensory organisation, the time dimension will not be continuous but intermittent, and each unit represents one trial. With these restrictions, figure 49b becomes a representation of the appropriate learning curve, the average of many experiments with different animals, so that "chance" variations of the conditions will not appear as significant. Hull (1943, 1947), gives the general equation for empirical curves of this description as

$$_sH_R = M\ (1 - e^{-iN})$$

In Hull's equation		In the 'servo' equation
M = 100% attainment (i.e., 100 habs.)	.....	A = the value of the step function to which the organism approaches
i is an empirical constant	...	K is an empirical constant
N is the number of trials	....	$t-t_o$ as defined above will be the number of trials.

The units of θ_I and θ_o must be the same. In Hull's equation, percentages are used for M, and S^H_R will therefore also be a percentage. If we can assign quantity to an objective stimulus complex, then at any moment, the sensory organisation will be capable of being expressed in the same units. This approach to the problem will warrant much attention, owing to the simplicity and economy in preliminary postulates, necessary to predict the empirical equation.

Other terms in the equation, in the successive approximations to the individual learning curve, will be of higher order e.g. $I \frac{d^2\theta_o}{dt^2}$ and $J \frac{d^3\theta_o}{dt^3}$. With these, the stability and damping of the servo loop must be considered. Figure 50 illustrates the results of experiments one, four and five. The average reaction times to the first eleven stimuli of each test, have been plotted. The steep rise of the curves in the first three reactions of experiments one and four, and the even steeper ascent of the curve for experiment five, flatten and then start to oscillate. There is a tendency for the oscillations to increase in amplitude. It is not known whether any significance is to be placed on the fact that the oscillations are partly in phase. At

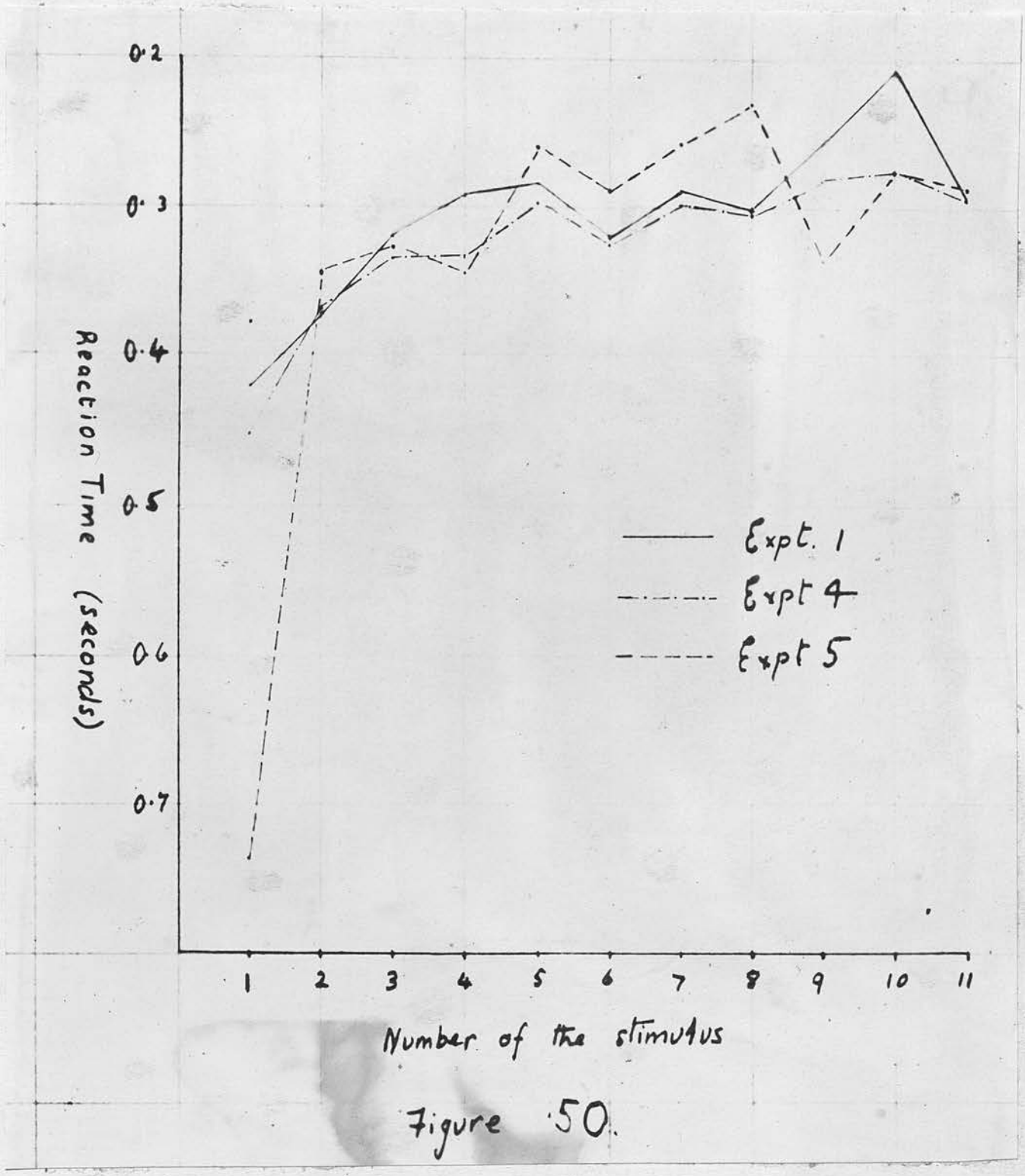

0·2
0·3
0·4
0·5
0·6
0·7
Reaction Time (seconds)
Expt. 1
Expt 4
Expt 5
1
2
3
4
5
6
7
8
9
10
11
Number of the stimulus

Figure 50.

At least there is probably no reason to consider any differences in the mechanisms operating in each experiment.

The individual learning curve will most certainly follow a more complicated system than the foregoing. One factor is hypothesis formation, in the face of a random set of stimuli: If the brain is to function normally by "ordering" or "relating", then hypothesis formation is bound to take place. In terms of the present analogy, hypothesis formation appears as an intermittent inertia in the mechanism, producing sudden jumps in the output, and theoretically, instability in the locp. The suggestions of this section are in line with Ashby's concept of the systems of interaction of the brain and environment (Ashby 1952). Intermediate states, of partial equilibria towards a final stable state, are similar to the above. Similar types of considerations have been developed by Von Foerster (1949) for memory functions, working from the data of Ebbinghaus, and in a recent theory of the engram, by Cragg and Temperly (1954, 1955). The latter is developed by analogy with certain aspects of the atomic behaviour in ferromagnetisation. The near certainty of neuronal interaction by sheer proximity (a neurone is within the dendritic field of a thousand others) and the consequent equilibria stated by domain patterns, are considered to offer a testable explanation of memory functions. They suggest (1954), that the electroencephalograph offers the best method of test.

In conclusion, in the words of Ashby (1952).

"Any system which shows adaptation must (1) contain many variables that behave as step functions (2) contain many that behave as part functions, and (3) be assembled largely at random, so that its details are determined not individually, but statistically ..... Such a system has a fundamental tendency, shown most clearly when its variables are numerous, to so arrange its internal pattern of action that, in relation to its environment, it becomes stable".

CHAPTER 15

Concluding Remarks.

The experiements in this paper were of an exploratory nature, and the questions raised are best left in the context of the experiments.

In general, the difficulty and labour involved in the analysis of records, and the relative uncertaintity of the outcome with the present (time series) method of recording, makes it of first importance to develop new and improved methods. The work of Walter and Dawson, who has been mentioned, with different ends in view, are making important advances in this field.

One of the main problems, in the relationship between Psychological and Electroencephalographic studies, is the selection of data.

Both fields of study are complicated by uncontrollable factors, possibly the same ones, and both can be viewed from a variety of different standpoints. It is suggested that the following classification of aspects of study should be used.

1. The organism may be examined in

a) states of rest e.g. the resting E.E.G., pulse, metabolism etc. or in

b) responding to various representative ingoing signals, by which the two fields of study may be compared in their data e.g. change in the steady state constants.

Evidence for this from the work of Darraw and others, was given in section one.

Many writers have referred to this type of classification.

For example, this subdivision is made by Kreezer (1938), in a slightly different form. He talks of psychological "capacity" and "activity", by which he refers to the organised processes and the testing of them respectively.

2. The response of the system to stimulation (1b above) may be analysed in two ways.

a) In terms of the changes that take place in system as a result of an ingoing stimulus, that is the signal (stimulus) as an operator on the matrix representing the system.

b) The changes in the signal as it travels through the circuit, i.e. the system as an operator on the signal matrix.

It may not be valid to induce the answer to one subdivision from the evidence of another. The fruitful and the non-fruitful studies may be examined in the light

of this work.

The alpha rhythm is an observable effect of the resting state of the brain (Lindsley, 1951). It is, therefore, part of the steady state. By applying a visual stimulus, we have the blocking of the alpha rhythm, i.e. change of the steady state (The evoked potential, if observed, would be a change in the signal as a result of the system).

Attention, as it has been defined, is a change of the system, and so we would expect to relate attention to alpha blocking. The work has been fruitful. Sensation and perception are the results of the system acting on the signal, and are easily related to the evoked potential and after effects, but not to blocking of the alpha rhythm.

Personality and intelligence have been studied in relation to the frequency and amplitude of the alpha in the resting state (see Section 2). Are they not steady state constants? The answer is yes, but we have no idea what they are. What we really know of intelligence and personality as organised systems, are a series of results from tests which, of course, are systems under stimulation. The experimenters have correlated results from the resting state with those from activity without conclusion, or with one experimenter finding one relationship, and the next the opposite.

There is an increment of alpha frequency with age (Lindsley, 1936, 1938, 1939), up to the age of 10 or 11 years. This would, of course, produce a correlation with intelligence over one individual. With a group of 48

8-year-olds Knott reported a correlation of 0.5 between intelligence (Stanford-Binet), and alpha rhythm frequency. He found no significant correlation for a similar group of 12-year-olds. Lindsley (1938) with a group of 88 children of 8 - 14 years, found no significant relationships. Kreezer (1939), showed that in mental defect, due to hereditary causes, and in mongolian types, there is a relationship with the E.E.G. Other than the above results, most authors, notably Shagass, 1946, with 1100 adult subjects, agree that intelligence, however measured, bears no relationship to any frequency, amplitude, or percentage time characteristics of the alpha rhythm of the E.E.G.

Numerous studies of the E.E.G. and personality have been carried out, mainly with reference to the psychological disorders. Notably Berger (1931, 1933, 1937), Lemere (1936, 1938, 1939, 1941), Grinker and Serota (1938), McMahon and Walter (1938) Rubin (1938), Davis and Davis (1939), P. A. Davis (1940, 1941, 1942), Walter (1942), and Yeager and Baldes (1937), have examined the E.E.G. in frequency and amplitude, percentage time and regularity of alpha rhythm. The evidence shows that there are various deviations from normal in the E.E.G. of psychiatric groups, but that consistency has been lacking, and the overlapping of the patterns with those of normal and epileptic groups, has led to many opposite conclusions and a great deal of choas.

In one of the few positive results in the classification of personality and its relationship to the

E.E.G., Lemere (1938), and Saul et al. (1937), the common factor, it seems, is the degree of involvment of the autonomic centre. That is, the attention which the subject is liable to be paying to his environment.

Walter and Walter, 1949, conclude that, "The difficulty may be due to the inaccuracy of the differential diagnosis of the clinical state, or insufficiently detailed analysis of the E.E.G. records, but it seems likely that the pathological basis of the psychoses, whatever it is, is not reflected in the overall picture of the cortical activity shown in the E.E.G."

From the classification given, it may be predicted that changes in the cortical activity, as a result of stimulation, will be related to the responses of the subjects to tests, and also possibly vary with the clinical picture.

The evidence in this paper indicates that, despite the modern pessimism, although, psychological correlates of the E.E.G. may not be in the conventional terms to which we are accustomed, they are present, and it can be concluded with Walter (1950, p.212) that, "a rich field awaits the patient cultivater".

SUMMARY

The Time of Perception: Factors, governing the time of pereeption, have been separated into two clases viz. Those preceding the stimulus and those following it. To the first class, the general title, 'set', has been given. This has been shown to subsume three mechanisms, sensory organisation, attention and motor organisation.

Sensory organisation has been examined in its

development and effects. The development is typified by a series of stages and regressions, either spontaneous, or as a result of atypical events. It affects attention by controlling it, and reduces the time to respond to an expected stimulus. Hebb's and Ashby's theories are referred to, for mechanism. At a different level of description, the state of readiness of the brain has been defined as subjective probability. This is a scaler quantity derived from the reaction time, as a result of Hicks evidence on the constancy of the rate of gain of information. It is suggested that time of perception be defined as, the average time to gain (signal the reception of) unit information.

There is evidence that it is possible to consider an individual reaction time as representative of the state of the brain at the arrival of the stimulus i.e. the subjective probability. Attention, it was concluded, is the negative correlate of the alpha rhythm. It is a priming, motivational mechanism operating in two distinct ways, facilitating the development of an adaptation (sensory or motor organisation), and priming the organism when the present adaptations are at varience with the external state of affairs: The load stress i.e. the rate at which the organism has to work, at any instant, to carry out the task in hand (c.f. Conrad 1951, 1954 and 1955), has been shown to affect the attention, and reduce the percentage time which it drops between reactions. The motor organisation is considered analogous to sensory organisation and, throughout the experiments, is assumed constant. In a recent work

(Alport 1955), set is described as "not separate from the perception or the overt act, but is .... a lower or subthreshold energic level of the perception or act". It is "largely tonic, is like the full or phasic stage of the aggregate, a dynamic pattern". Freeman (1939, 1940a and 1940b) has provided the data to the motor aspects of Alports conclusion. It is considered that the results in this paper substantiate the sensory organisation parts of the concept. On the arrival of the stimulus, a central "organisation" has to be undertaken, (Welford). Two organisations may not take place at the same time; the second is held over until the motor act to the first. If the act contains more than one movement, the organisation to a second stimulus, which arrived before the response to the first, may start at the begining of the first movement, or just before the second. Different subjects showed one of the two patterns of behaviour. Evidence exists that the visual mechanism contains a device which averages over one tenth of a second, with the result that the time of visual perception is increased, by an average of .05 second, compared with the minimum possible, with combinations of stimuli to other sensory endings. The cerebral activity. The alpha rhythm is shown to develope in amplitude and duration, as a result of a regular pattern of behaviour, and to be related to the length of the intervals between stimuli. There is no evidence that a "new pattern" of alpha waves is developed, but the existing fluctuations become organised. When the stimuli has characteristics recognisable in frequency, it

was shown that a semi-permanent change in the frequency of the resting rhythms occurs. (the stimulus was responded to in the usual manner by releasing the finger from a key). In the course of the reaction, if a preparatory signal is given, a cerebral discharge, in preparation for the stimulus, occurs in all areas of the brain. This discharge is shown to be modified, by the occurrence of the "stimulus in the occipital area, and by the preparatory response in the parietal and central areas. The phases, at which the preparatory and the response movements take place, are shown to be centred on 90 and 270 degrees. The cerebral activity is shown to be associated with the various parts of the preparation, the stimulus and the response, and consistent patterns are present between stimulus and response for a given reaction latency.

APPENDIX 1

EXPERIMENT ONE.

Detailed description of results.

Figures four to eighteen are presented together, with detailed descriptions to outline the development of the patterns. Summaries will be found on page 53.

a) The Twelve-Second Standard Interval

In figure 4a, (subject 91) the first line is the record which included the instruction, "eyes open" at x. The lines have been numbered as for subject 98 (figure 3).

Interval 2: Alpha activity first appeared as a ripple after the second stimulus and before the mid-point of the interval.

Interval 3: The amplitude of the first burst has increased.

Interval 8: It is seen to have increased both in amplitude and duration after which the amplitude increases, whilst the duration tends to be diminished.

Intervals 11 & 12: Maximum amplitude is reached in the first burst, meanwhile, the activity circa the mid-point has diminished.

Intervals 13 & 14: The same pattern (thirteen omitted) is shown.

Interval 15: Alpha activity reappears just before the mid point of the interval.

Interval 16: The above is repeated together with some evidence of an alpha-like ripple, starting about two seconds from the end.

Interval 19: The activity, late inthe interval, has increased in amplitude, but that of the other two bursts, seen

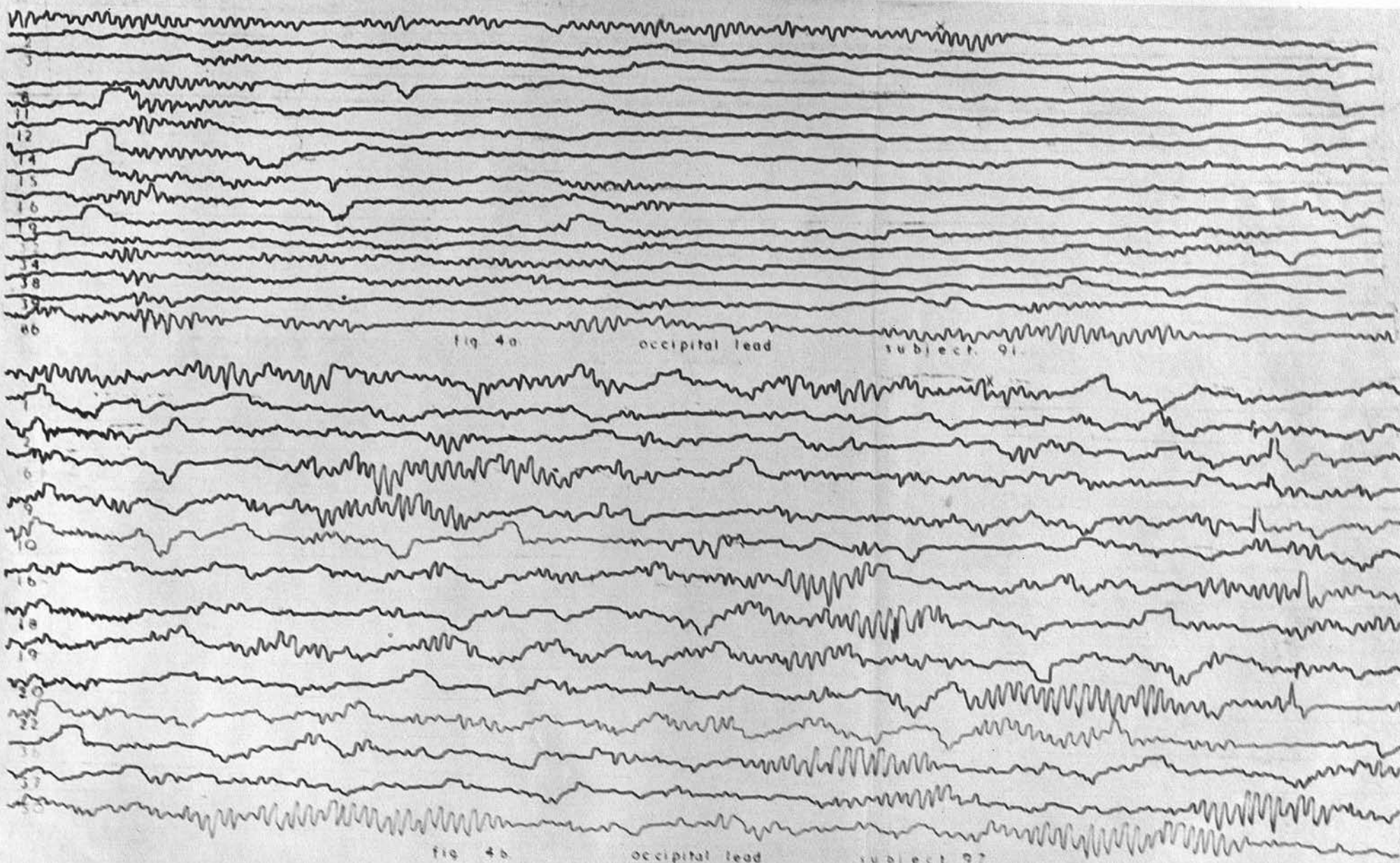


fig 4a occipital lead subject 91
fig 4b occipital lead subject 97
seconds
50 μ volts

FIG 4.

in previous intervals has diminished appreciably.

Interval 20: Showed the same result.

As part of the experiment the twenty-first interval was one of only nine seconds. The effect of such a distrubance to the development sequence, is "regression" to patterns observed earlier in the series).

Interval 32: This shows the next appearance of the "advanced" pattern shown in interval nineteen

Interval 34: This shows an increase in the amplitude and also in the duration of alpha activity in the first half, but the amplitude of the later burst is diminished.

Interval 35: Was not of twelve seconds, and the same pattern as thirty-four is not again observed until interval thirty-eight.

Interval 39: This, once again, showed a diminution in the duration of alpha rhythm in the first half, separating the activity into two distinct bursts, and an increment in the amplitude of that in the second half.

Interval 86: A clear example of what appears to be the most advanced stage reached by this subject. The amplitude of all three bursts gradually increased between intervals 39 and 86 in spite of occasional non-standard intervals. It will be seen that the bursts of alpha activity at the end of the intervals have gradually assumed an earlier position on the record, as the experiment progressed.

In the record of subject ninety-seven, figure 4b, a similar presentation has been made. The amplitude

is greater, but the percentage time of alpha activity with eyes closed, is slightly less than in subject 91, figure 4a, as is shown in the first line of the record (x marks the instruction "open your eyes".) There is some evidence of activity, in very small bursts of two or three low amplitude waves, after the first stimulus (second line, figure 4b).

Interval Two: After the second stimulus, alpha activity occurs at two points in almost full amplitude, these points being symetrically arranged in the interval.

Interval Six: The alpha activity in the first half of the interval increased in duration, and that in the second half, though lasting longer, is seen to be reduced in amplitude in the sixth interval. During this interval the alhpa rhythm is extended to include a large proportion of the first half of the interval. In the next few intervals, including the ninth, the patterns are much the same, but in the tenth the pattern has changed.

Interval Ten: Here, such alpha activity as there is, is concentrated more in the later portion of the interval with one small burst early in the second half and one at the end. Low amplitude activity can be seen in this interval in a small burst starting at about the same moment as the main burst in the ninth and earlier intervals.

Interval Fourteen: The difference between the two semi-intervals has become more marked, and the alpha activity has increased in amplitude and duration, in points corresponding to those observed in interval ten. Only small bursts are observable in the first half.

Interval Eighteen: There is an indication of reduction in all bursts other than the main one, just following the

mid point of the interval.

Interval Nineteen: A marked change occurs. Small spindles of moderate amplitude are observable over both halves of the interval, with two in the first half and one in the second. This state corresponds to the third classification made, i.e. fig. 3d.

Interval Twenty: This shows an almost complete diminution of alpha activity in the first half, and a shift and extension of the main burst in the second half, so that it now occurs halfway through this half of the interval.

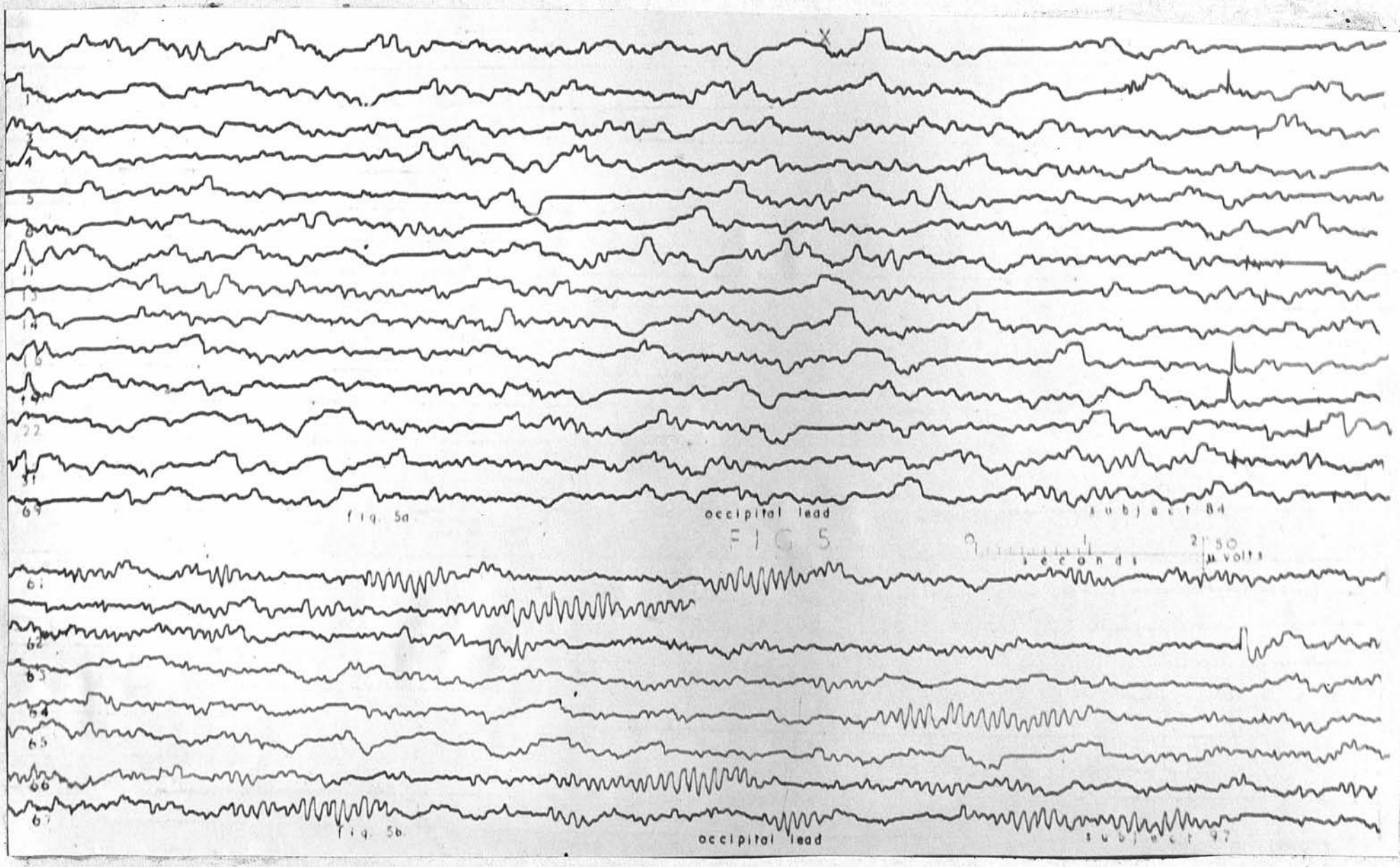
Interval Twenty-One: Was not of twelve seconds, and the interval twenty-two shows a return to a pattern similar to that seen in interval nineteen, with the exception of the main burst.

Interval Thirty Six: Following a non-standard interval, the pattern is similar to that first seen in interval fourteen.

Interval Thirty-Seven: The main burst, just after the mid-point, has decreased in duration, and there is the appearance of a spindle of alpha activity, starting about two seconds from the end of the interval. In following intervals, the pattern returns to that of interval twenty, only to be disrupted by a non-standard interval.

Interval Fifty: The most advanced stage reached by this subject is first observed.

Between the two records shown here, many differences, in the acquisition of the final pattern, are observable. It is however, possible to note the same general series of stages. Any stage may become prolonged in one subject,


X
1
4
5
11
13
14
16
22
31
69
fig. 5a
occipital lead
subject 84
FIG 5
seconds
50
μ volts
61
62
63
64
65
66
67
fig. 5b
occipital lead
subject 97

barely noticeable in another, or consistently returned to after disruption in another. The most important point is that there is such a development.

One other point emerges. Subject 91, in figure, 4a, shows alpha activity as much as 1.5 seconds earlier in each interval than subject 97, figure 4b, and subject ninety-seven does not show the burst just before the mid-point. This gives the impression of either this position or that, for the bursts. C.f. also the last seven lines of figure 4b. This may be evidence to support the suggestion of two sources of alpha activity, in a sense in opposition.

The "nodes" at the centre-point of the intervals are well marked in both subjects.

In figure 5a, excerpts from the recordings made from subject 84 are shown. This subject is predominantly a "non-alpha" type. Large, slow activity is punctuated by small, faster waves, some of which are about the alpha frequency. In the first line a certain degree of flattening is observed at the order "open your eyes", at x. The square wave following x is the result of the muscle potential of the action of opening the eyes. This slight flattening is still recognisable in the first few intervals, but, as with other subjects, the difference is lost as the experiment progresses. There is evidence that waves at alpha frequency occur in the first interval. In the third interval, alpha activity is more prolonged, and is superimposed upon rather large, slow waves and overlayed by

smaller, fast activity. This occurs for a greater percentage of the time in the second than in the first half of the interval. This persists in the fourth interval, waves of eight to eleven cycles being in evidence.

Throughout the remainder of the record, the percentage time and amplitude of eight to nine cycles per second wave forms are seen to increase. Other dominant frequencies occur in the follwing spectra: less than 1 c.p.s., 2-4 c.p.s., 5-6 c.p.s., 12-16 c.p.s., 16-20 c.p.s. and 30-40 c.p.s. At different times, all but the last two appear at a fairly high amplitude. Large amplitude activity in the alpha range, occurs mainly in the second half of the intervals until the sixth interval when, from this point, it can be observed in both halves, most often with two bursts over each interval.

There seems to be a certain degree of similarity in the occurrence of the slow activity, especially in waves of two to three cycles per second, in the records fourteen to twenty-two. These waves may, in some cases, be interpreted as artifacts due to blinking. This is doubtful, but the most that can be said is that such waves do not appear to take on properties such as have been noted for alpha activity.

In the non alpha type, the alpha activity tends to show increments in amplitude and duration as the experiment proceeds.

The most commonly occurring pattern in the later

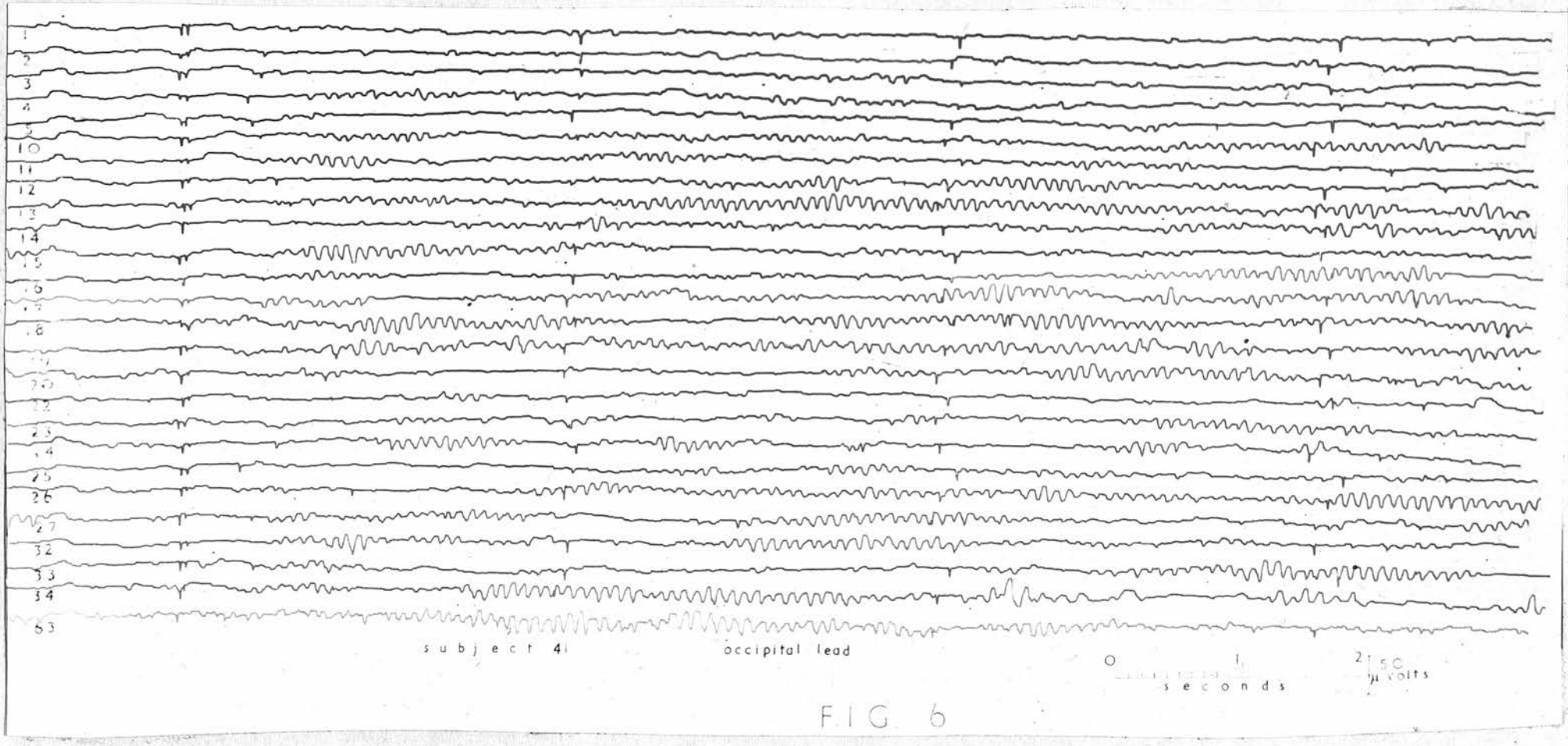


FIG. 6

stages, is that as shown in the last two lines of recording in figure 5a, i.e., a main burst near the end of the interval, and some indication of alpha activity near the centre of the interval.

Figure six, summarises the record of subject 41. This record was taken in the course of preliminary investigations with a mechanical oscillator which provided a considerable amount of interference, such that, in each line of record, we have four artifacts, the first one double. These are easily recognisable, however, especially with the mode of display adopted here. The frequency time characteristics of the switch potentials, clearly single them out from the electroencephalograph. This record was included because, of all subjects tested, this one showed the highest percentage time of alpha activity at the earliest interval i.e., in interval thirteen the pattern is closely related to that finally observed much later in the record.

The first two intervals show very little alpha activity except for a short burst of a few waves starting after about 10.5 seconds of the second interval, and lasting a few waves. Interval three: This shows a burst of moderate but irregular amplitude following the mid-point of the interval, and again later, as in interval two. Interval four: This repeats the above pattern together with a long burst in the first half. The alpha activity at the centre of this interval persists over the mid-point in a burst of three waves, with the remainder of the activity separated on each side. The activity in the later seconds of the

interval is reduced, compared with earlier intervals, to a very low amplitude.

Interval five: Here is the occurrence of a burst of low amplitude in the second half, at a point earlier than the alpha activity in the previous intervals. Other low amplitude ripples occur in this interval in positions similar to the bursts in interval four.

Interval Ten: This shows the next significant change. The activity occurs in the first half and the centre of the interval, in much the same way as in interval four, but the third spindle of activity, i.e. in the second half, is extended in amplitude and duration to last about 2.5 seconds, with gradually increasing amplitude and an abrupt blocking about 0.75 second before the next stimulus was due.

Interval Eleven: This shows similar patterns over the whole period, except that the central burst occurs before the mid-point, and the main burst, in the second half, now occurs for a much shorter period and starts slightly earlier, than that of interval ten.

Interval Twelve: The main burst in the second half, is increased in amplitude and duration, and occurs still earlier in the interval. The central burst starts as a low ripple, increases in amplitude just after the mid-point of the interval, and ends abruptly after a few waves of high amplitude. The burst in the first half of interval eleven is not visible in this interval.

Interval Thirteen: This showed the greatest percentage time of alpha activity and it is mainly composed of a long

burst, starting before the mid-point of the interval and continuing until two seconds before the end of the interval. Waves at alpha frequency are present over the period immediately following this, and 0.5 second later, the first of two more spindles which occur in the last seconds of this interval is seen. Other alpha activity in this interval is seen in the first half, nearly corresponding to the first burst in interval eleven. The frequency of this activity is higher than that of the other spindles.

Interval Fourteen: This shows a regression from the conditions of interval thirteen. Alpha activity occurs in a single wave and a low amplitude ripple in the first half, and three short bursts at the end of the second half of the interval.

Interval Fifteen: This shows a similar pattern to that of interval four, with a large amplitude burst in the first half interval, and low amplitude activity in short bursts in the second half of the interval. The amplitude of the few waves over the mid-point is considerably less than that of interval four.

Interval Sixteen: There is a repetition of the pattern found in interval ten, with the exception that the ripple over the mid-point is lower in amplitude.

Interval Seventeen: This shows a pattern similar to interval twelve, except that a burst of alpha activity occurs in the first half of the interval, and that there is a repetition of the long, abruptly finishing spindle noticed first in interval ten and again in sixteen.

Interval Eighteen: The alpha activity is extended to include a large proportion of the first half. Immediately after the mid-point of the interval, a spindle of varying amplitude starts, which terminates half way through the second half. A further spindle of lower amplitude starts a fraction of a second later.

Interval nineteen: All bursts are extended in duration, but the amplitude is more irregular. In terms of duration this interval shows a pattern most similar to that of

Interval Twenty: This shows a complete change from this pattern. Alpha activity in the first half is limited to two or three small waves. In the second half, however, a small amplitude burst can be seen following the mid-point, and a large amplitude spindle occurs halfway through the second half of the interval. A further small burst is seen at the end of the interval. (Interval twenty-one was of 9 seconds. Its effect is to diminish all activity with the exception of six waves at alpha frequency, in the next interval).

Interval Twenty-Two: Three waves at alpha frequency occur, halfway through the first half and three, a little over halfway through the second. This pattern is most similar to interval two. Interval Twenty-Three: Three small bursts, two in the first half and one in the second, are overshadowed by a long spindle of large amplitude in the last quarter of the interval.

Interval Twenty-Four: The duration of the counterpart of

the spindle in interval twenty three is considerably reduced, whereas the amplitude and duration of bursts earlier in the interval are increased, with two bursts before the mid-point and a small burst of beta waves just after.

Interval Twenty-Five: The diminution in the amplitude recurs. Small bursts can be seen just before and just after the mid-point, and halfway through the second half of the interval.

Interval Twenty-Six: Activity at alpha frequency is seen to extend over the greater part of the interval. Three bursts are perhaps separable, one before the mid-point, one after, and one in the last seconds of the interval.

Interval Twenty-Seven: Was one of 15 seconds. The first twelve seconds of the record of this interval is included, since it is directly comparable with the foregoing. The pattern is much the same as in interval eighteen, being a burst in the middle of the first half, and having one starting at the mid-point of the interval, but with a lower duration.

Interval Thirty-Two: The effect of the non-standard interval was again to cause a regression, and the patterns, as seen in the first 12 seconds of interval twenty-seven, next occurred in this interval.

Interval Thirty-Three: This does not substantiate the advance and shows a pattern first seen in interval ten and again in interval sixteen.

Interval Thirty-Four: This once again shows a high percentagetime of alpha activity in one burst, starting this

time in the centre of the first half and continuing into the second half of the interval. This pattern was the final pattern to which, after disturbances, and if the number of standard intervals allowed, the activity returned. This is much the same as that late in the experiment e.g.

Interval Sixty-three: There is an increase in the beta activity in this interval and in others, at this stage of the experiment.

The effect of a non standard interval.

As seen, a "regression" to an earlier pattern most often occurs followed in succeeding standard intervals by a regrowth or redevelopment.

This serves as a useful check to the estimated development. Figure 5b is composed of a series of successive intervals from late in the record of subject ninety seven (figure 4b) after the pattern is well established, and the first line of record is a non-standard interval of eighteen seconds.

Interval sixty-one, is of eighteen seconds, which, for reasons of space and ease of observation, was cut at the point corresponding to twelve seconds after stimulus sixty-one. The remaining six seconds of record of the sixty-first interval, are included underneath as the second line of figure 5b.

The pattern of the first twelve seconds can be compared as a standard interval, and it is most similar to that of interval nineteen, see figure 4b. The remaining six seconds up to stimulus sixty-two are not comparable.

Interval Sixty-Two: The third line of figure 5b, is the

record obtained from the twelve seconds following the non-standard interval. The alpha activity is reduced, but present to a greater degree than in interval one, figure 4b. There is no dominant spindle formation.

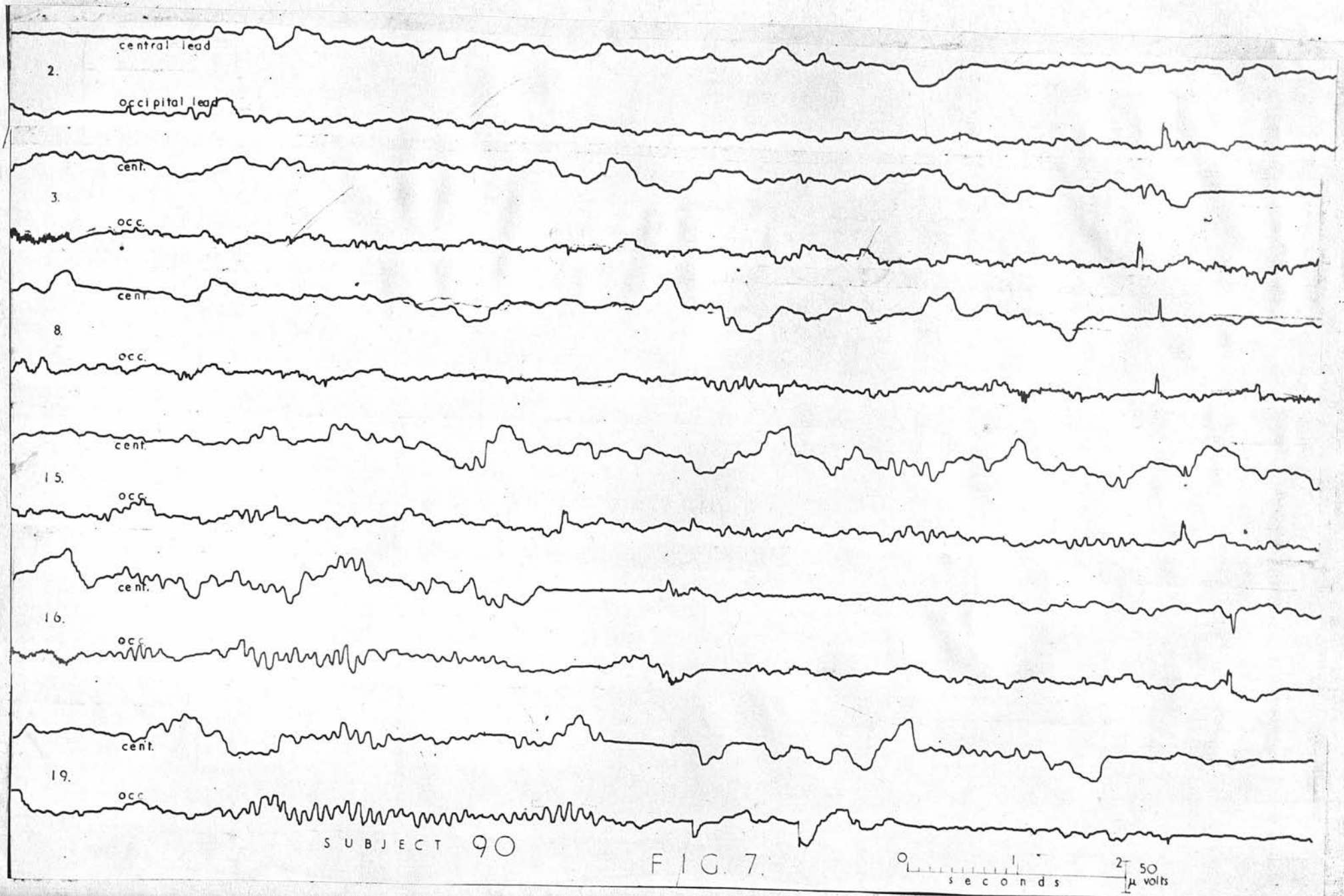
Interval Sixty-Three: The alpha activity is increased slightly in amplitude, and the positions of this activity have changed. The record shows signs of three bursts, one in the first half, one over the central period, and one in the second half.

Interval Sixty-Four: There is a return to the familiar spindle formation, and this line of record is very much the same as the pattern first occurring in interval twenty, figure 4b.

Interval Sixty-Five: This spindle formation has again disappeared, and there is an increase in slow, one to two cycles per second, activity. This pattern may be thought to be a regression, or it may be considered to be of the form of pattern noted in figure 3d. The former is, I think, the better explanation, since this type of spontaneous regression is very common in this experiment.

Interval Sixty-Six: It shows a pattern not previously obtained from this subject, a pattern most similar to intervals sixteen and eighteen, figure 4b. The alpha spindle, however, occurs earlier in interval sixty-six, and about five seconds after the stimulus, finishing at about 2.5 seconds later. There is also a burst of low amplitude alpha waves in a position corresponding to the pattern in interval sixty-four.

Interval Sixty-Seven: Last Line, figure 5b: The pattern



SUBJECT 90

FIG. 7.

is most nearly similar to the pattern occurring before the disruption, i.e. in the first twelve seconds of interval sixty-one. There are differences, however, especially in the first half of the interval, and it is more nearly the same as the most advanced pattern shown by this subject, as first seen in interval fifty (figure 4b).

The pattern from the central Lead (Figures 7 & 8).

To compare the two - the record from both channels is included, and so each interval is represented by two lines of tracing, the upper from the central lead and the lower from the occipital, as they were recorded.

Figure 7
Interval Two: In the first pair of records shown, neither lead shows alpha activity at more than very low amplitude, and this, late in the interval.

Interval Three: The occipital record shows an increase in the amount of low voltage alpha activity, with very little increase in the central recording. From this point, the alpha amplitude increased in the second half of the intervals.

Interval Eight: A marked spindle can be seen in the occipital record. This interval was the first in which alpha activity in the central lead was clearly visible, in two or three waves of low amplitude.

Interval fifteen: The alpha waves can be seen in both halves of the interval, in both leads. In the occipital and central recordings, the bursts of alpha activity more or less correspond to one another.

Interval Sixteen: The correspondence between the two records

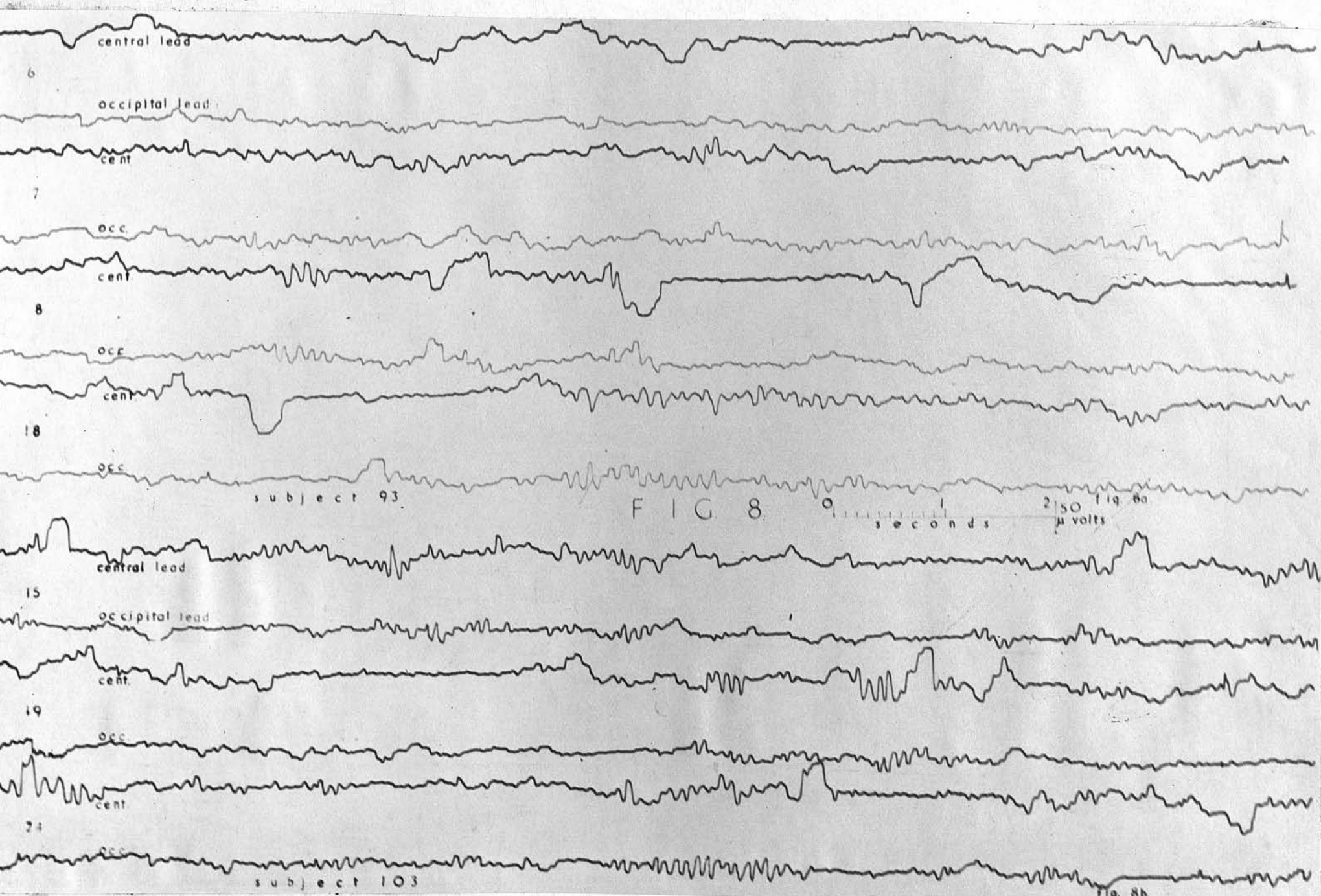

central lead
6
occipital lead
cent
7
occ
cent
8
occ
cent
18
occ
subject 93
seconds
μ volts
fig. 8a
central lead
15
occipital lead
cent
19
occ
cent
24
occ
subject 103
fig. 8b

FIG 8

is closer, and the dominant alpha activity is found entirely in the first half of the interval. This continues as illustrated by

Interval Nineteen: The first half shows the dominant burst once more. Some alpha waves may be seen at a moderate amplitude in the second half of the interval in the central and a faint ripple is visible in the occipital recording recording at the same position, and with a slightly larger amplitude, a little later.

From this example, the order of relationship may be appreciated. Initially, it is not apparent, but after a few intervals, in which the alpha rhythm appears in the occipital recording, it starts to appear in the central recording. The similarity increases, and is retained for the remainder of the intervals.

In figure 8a, I have presented a summary of the changes in the relationship between leads in the recordings from subject ninety-three. Alpha rhythm was first seen in the occipital record in interval four, and occurred in the centre of the second half of the interval. The pattern persisted through

Interval Six: The upper line is the record from the central region, and that from the occipital region is recorded in the lower line.

Interval Seven: Alpha rhythm can be seen to occur in three small bursts in the central recording, two of which are simultaneous, with alpha in the occipital record.

Interval Eight: Shows a change of balance from the second, to the first half, of the interval. Alpha activity occurs

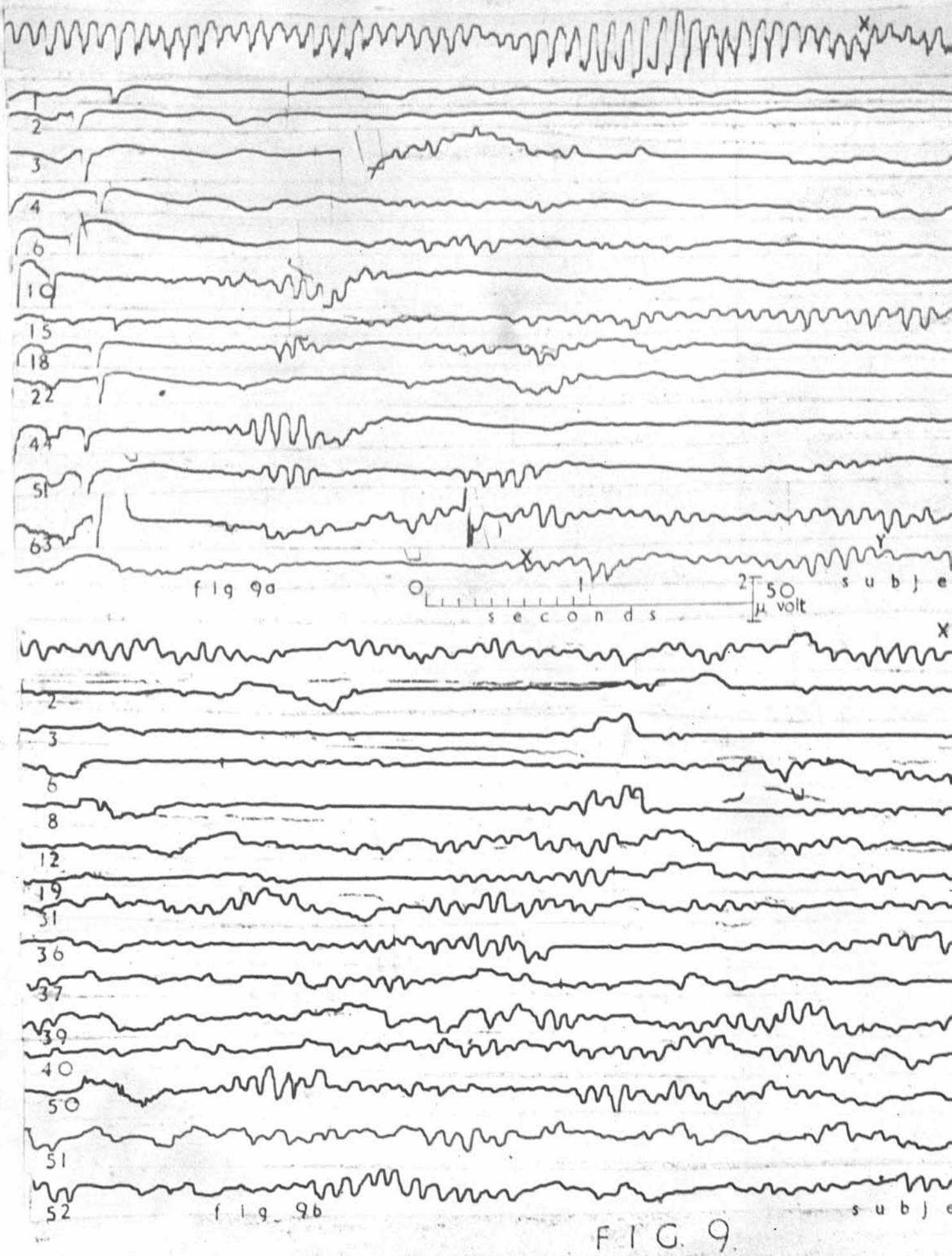

1
2
3
4
6
10
15
18
22
44
51
63
X
Y
fig 9a
0
1
2
seconds
50
μ volt
subje
X
2
3
6
8
12
19
31
36
37
39
40
50
51
52
fig 9b
subje

FIG. 9

in both leads to the same extent. From this point the records both follow the same pattern. For instance,

Interval Eighteen: The occipital record shows a burst of alpha activity at the centre of the interval, and the central record corresponds closely to this.

Figure 8b, further illustrates that, in the course of the series, the alpha activity in the central lead changes in parallel with that in the occipital lead. The records of intervals fifteen, nineteen and twenty-four from subject one hundred and three, are included.

Interval Fifteen: This shows the occurrence of alpha activity, mainly in the first half interval, (upper line central, lower line occipital recording). This first occurred in interval nine and it continued until interval eighteen.

Interval Nineteen: The alpha activity is limited to the second half.

Interval Twenty-Four: This was the first from this subject showing a burst of alpha activity over the mid-point. The occurrence of the alpha rhythm in the two leads is closely similar.

b) Standard interval of eight seconds.

Figures 9 to 12 illustrate the results.

In figure 9a, (subject 129), after the instruction to, "open the eyes at x", blocking was complete.

Intervals one and two: These showed no signs of activity whatever (switch potentials are unfortunately present in this subjects record at the begining of each interval).

Interval three: A burst of activity occurred in the second quarter of the interval, the begining being obscured as the result of a cough. The burst persisted until the centre of the interval.

Interval Four: This presents much the same pattern but with a lower amplitude.

Interval Six: The amplitude in part of the burst has increased. No alpha activity was shown in the next intervals.

Interval Ten: The burst, at a high amplitude, appeared much earlier in the interval. Intervals eleven, twelve, thirteen and fourteen: These were without alpha activity.

Interval Fifteen: This showed a unique pattern. A gradual rise of the amplitude of the alpha rhythm from its first noticeable point, after about three seconds of the interval, to its maximum and end, at about 6 seconds after stimulus fifteen.

Intervals sixteen, seventeen: These were the same as interval ten.

Interval Eighteen: This showed the next change. Activity is present in the same position as in previous records, plus a low amplitude burst, starting after about 2.5 seconds, and extending until about the mid-point. After the mid-point also, there is evidence of a very low amplitude ripple at alpha frequency.

Interval Twenty-Two: This follows the non standard interval. The pattern has returned to the first occurring, a low amplitude burst for one second, just before the mid-point.

The pattern thereafter, for many intervals, does not

develop further than that found in interval ten. The amplitude, however, increases and I have included interval forty-four as an illustration.

Interval fifty-one: This shows the next change, which is to a pattern similar to that of interval nineteen but with greater amplitude. This pattern was repeated occasionally before the

Interval Sixty-three. Showed the next change as these three bursts became linked. (A cough again produces an artifact). No further advances were observed in this subject. The final line was taken, starting 23 seconds after the last stimulus. The order, "release the key" was given at X, and, "close your eyes", at Y.

Subject 116 showed a typical series of stages. The first line was recorded with the eyes closed until after the order to open, which was given at x, after which blocking was almost complete.

Interval Two: Alpha activity was first observed in this interval. Low amplitude ripples can be seen early in the interval, just before the mid-point, and later, about half-way through the second half.

Interval three: This shows only the pattern just before the mid-point, and with two waves covering it. No waves were visible in interval four, and interval five was a repeat of interval two.

Interval six: This shows a low amplitude ripple in the first half and a long, low amplitude spindle in the second, followed by a burst of moderate amplitude which included waves of alpha frequency.

Interval Eight: A pattern similar to that of interval three is seen, with a low voltage ripple in the second half of the interval.

Interval Twelve: This shows an extension in duration of the pattern, as in interval eight. No further advance occurred for many intervals, except for slight increments in the duration and amplitude of the two bursts. I have included interval nineteen as an example.

Interval Thirty-One: Four bursts appear, two of moderate amplitude in the first half, and two of low amplitude in the second. After the next non-standard interval, thirty five, the pattern reverts to an earlier stage of two bursts only, but the amplitude of each is equal and fairly high, for this subject.

Interval Thirty Seven: There is a drop of amplitude, but this, in the first half. This pattern is most like that first seen in interval six.

Interval Thirty-nine: The amplitude once more increases, and two main bursts appear at each side of the mid-point, with two smaller ones later in the second half.

Interval Forty: This is most similar to that of interval fifteen for subject 129, except that the rise in amplitude is not steady in the main burst, and there is a small spindle of alpha activity for half a second, starting one second before the end of the interval.

Interval Fifty: The pattern is seen to change to three separate spindle formations, one at the begining, one in the middle and one at the end of the interval.

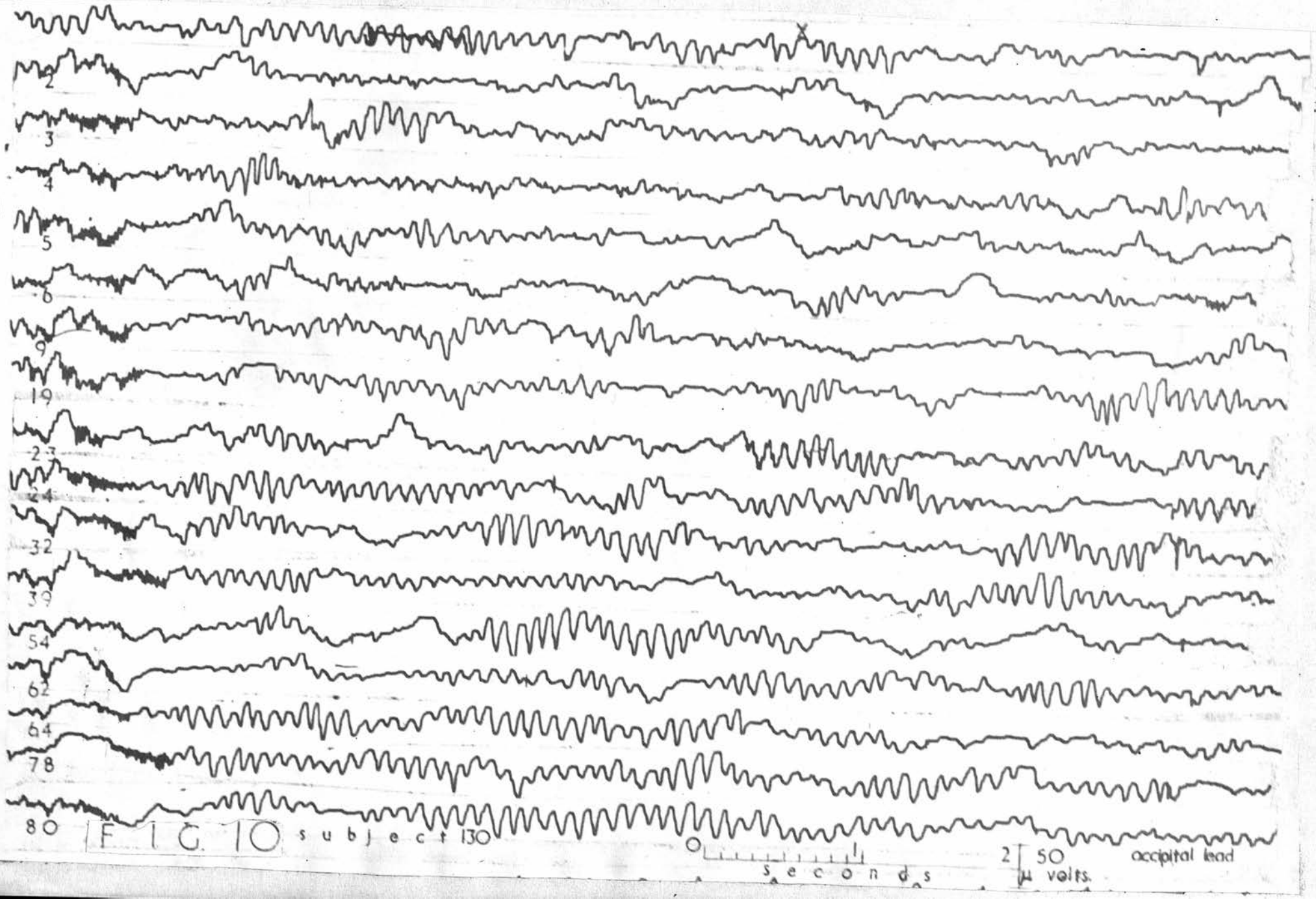


FIG. 10 subject 130

Interval Fifty-One: This shows what may be the first signs of the pattern as seen in interval fifty-two, or it may be a regression.

Interval Fifty-two: This shows two distinct bursts, longer than those of other intervals, one in each half interval and of equal amplitude over most of their lengths. This pattern was rare, but showed the maximum percentage time of alpha activity. It is difficult to say which should be regarded as a final pattern for this subject, this, or that of interval fifty, and those like it.

In subject 130, figure 10a, alpha activity with the eyes closed was not regular, but it did occupy a large proportion of the time. Blocking was by no means complete with the opening of the eyes after the order given at x, and small bursts of three or four waves were visible in the record. After the first stimulus and response, there was no difference in the duration or amplitude of alpha activity.

Interval Two: After the second stimulus, a very low amplitude ripple at alpha frequency is present over the whole interval. This is punctuated by waves of larger amplitude early in the interval, just at the half-way mark and, about one second later, in the second half.

Interval three: The low 'background hum' of alpha activity is broken by a large amplitude burst in the middle of the first half of the interval, and by a burst of moderate amplitude in the middle of the second half of the interval, in much the same position as the burst in the second half of interval two.

Interval Four: This shows a drop in the 'background' alpha, and the 10 per second activity is limited to a series of spindles of varying amplitude one, or perhaps two, in the first half, and two in the second.

Interval five: Nearly all the alpha activity is localised in two bursts which fill almost the whole of the first half of the interval. Some low amplitude ripples are visible, half-way through the second half.

Interval Six: This shows a diminution in the first half to a single short burst, and the growth in amplitude of a series of waves in the second half interval, much the same as the pattern first observed in interval four.

Intervals Seven & Eight: were the same as interval six (they will be seen with the central record in fig. 11).

Interval Nine: The pattern has returned to that first seen in interval five but with a further burst, which terminates just before the mid-point of the interval. A very small burst is also seen in a similar position at the end of the interval.

Interval Nineteen: This shows the next stage in development. The pattern is the same as that in nine, except for a burst of activity following the mid-point, and lasting about half a second. The burst at the end of the interval has become extended to start earlier, and lasts about 1.5 seconds. This pattern is upset in the twenty-first interval by the stimulus occurring after 6 seconds.

Interval Twenty-Three: There is a partial return to

earlier patterns with low amplitude activity, mirroring the long burst of interval nineteen, in the first half of the interval. The burst following the begining of the second half has become extended, and that of later in the interval has become lowered in amplitude and more irregular.

Interval Twenty-four: The first half is almost entirely taken up with a protracted spindle of alpha activity and a small burst starting before the mid-point and blocking just after. The major burst of the second half is again extended, compared with interval twenty-three, the burst at the end being contracted.

Interval Thirty-Two: This shows the first occurrence of a long burst of alpha rhythm in the centre of the interval. Apart from the very early part of the interval, the, 'either this position or that' rule seems to govern the comparison with interval twenty-four. This pattern is not seen again for a number of intervals.

Interval Thirty-nine: For instance, although following a similar tract in the second half of the interval, shows a node at the mid-point and lowered amplitude. The pattern of the first half is of two bursts, the first short, and with a larger amplitude than the longer second, which continued until the mid-point. This is rather similar to the pattern of interval twenty-three.

Interval Fifty-four: This shows a return to the condition of a large spindle ~~burst~~ of alpha rhythm over the mid-point. Activity in the remainder of the interval was decidedly less than previously, being limited to a high amplitude

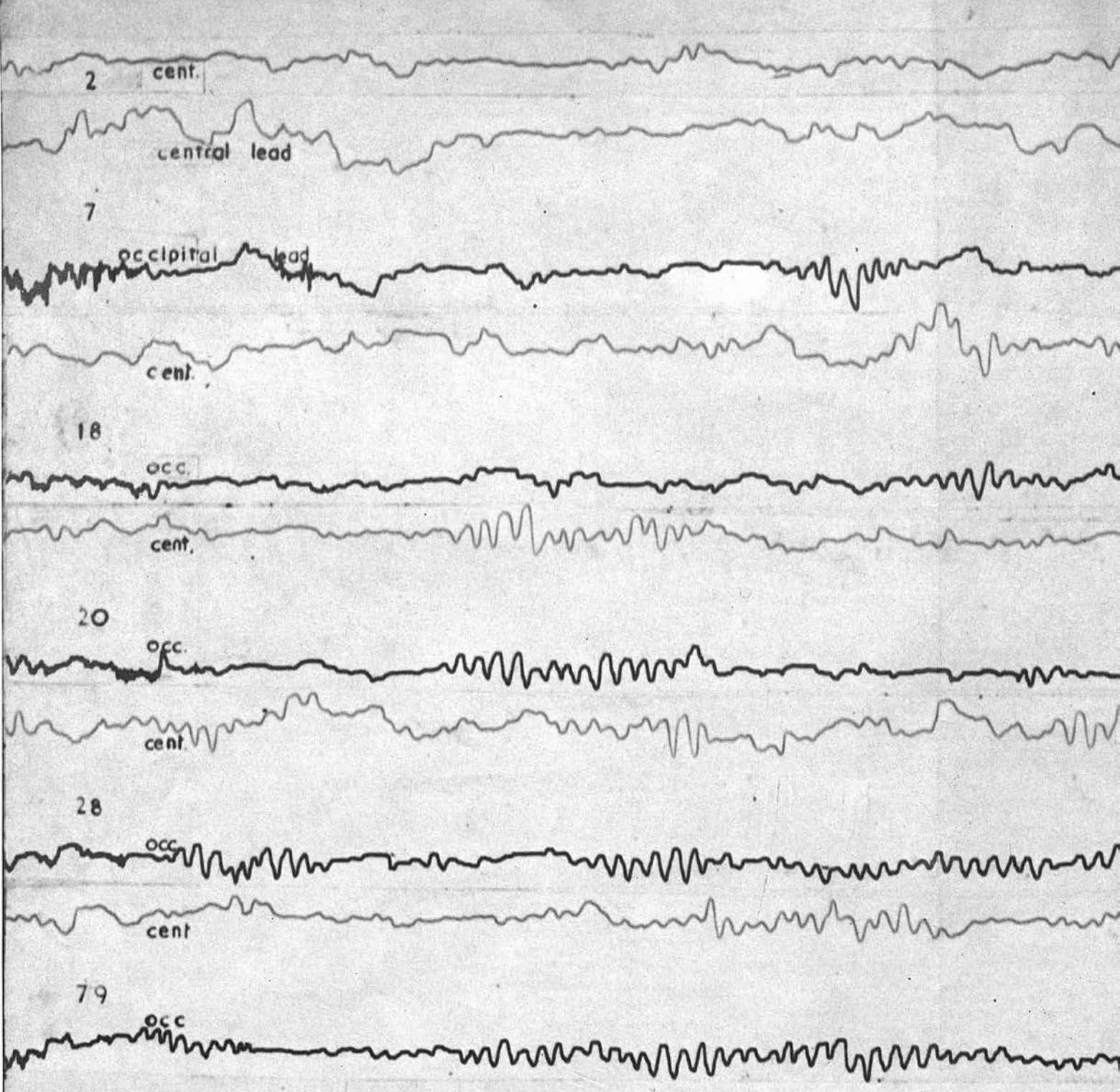

2
cent.
central lead
7
occipital lead
cent.
18
occ.
cent.
20
occ.
cent.
28
occ.
cent
79
occ
subject 130
0
1
second

FIG 11.

burst during the early moments of the interval, and occasional low amplitude ripples in the rest. Further disturbance again disrupts this pattern.

Interval Sixty-Two: This shows a return to the pattern first seen in interval nineteen. With two more standard intervals, however, the pattern is similar to that of fifty-four, except that the first burst of alpha activity is protracted to fill about two seconds of the first half of the interval.

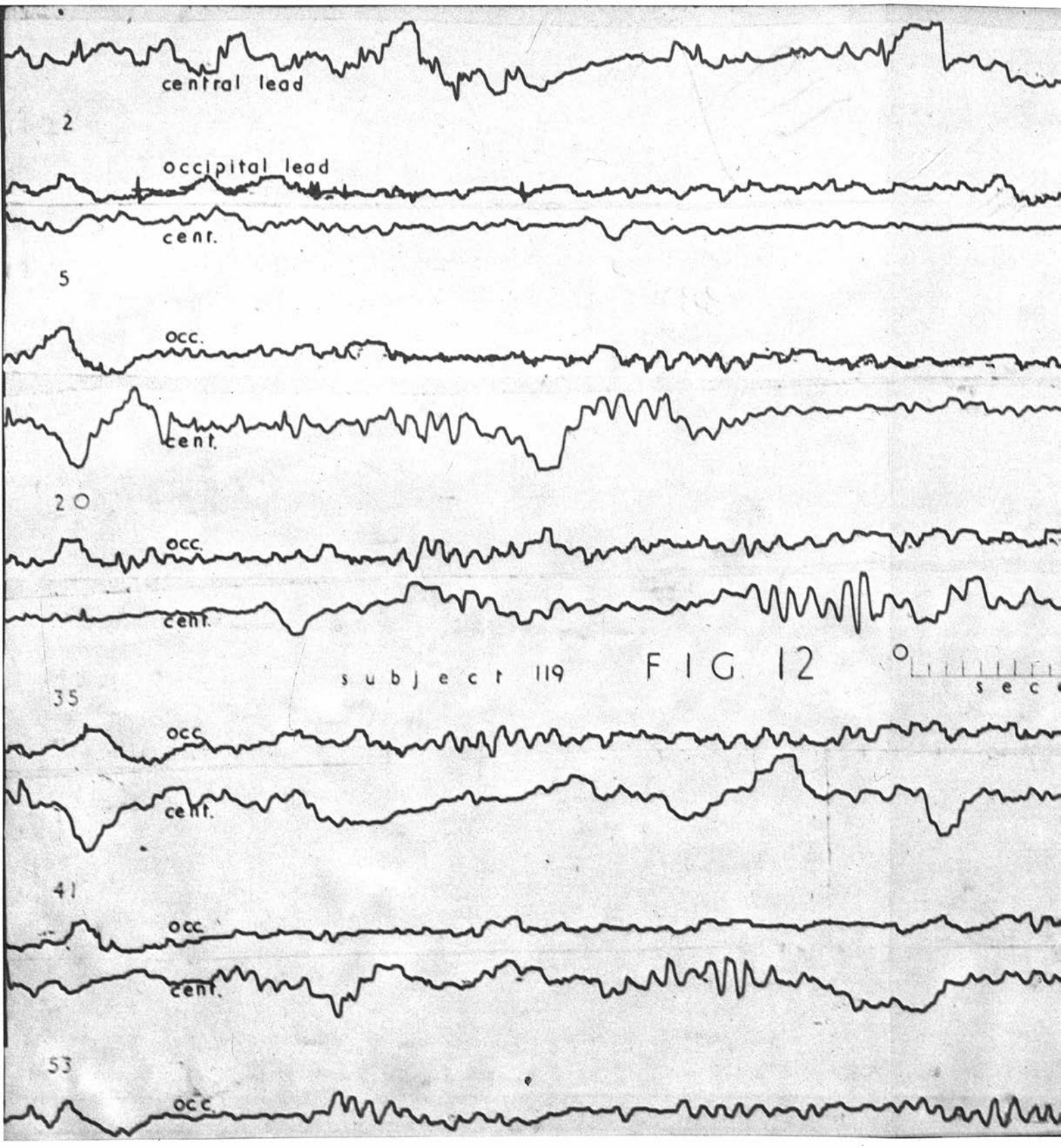
Interval Seventy-Four: This shows the highest percentage time of alpha activity, but the amplitude is irregular and there is evidence that the pattern is composed of three bursts. It is much the same as the pattern of interval thirty-two, except that the nodes between the spindles are not well defined.

Interval Eighty: This once more showed the pattern of interval fifty-four, with extended bursts, and seemed to represent the 'end pattern' attainable, with the order of repetitions as used in the experiment.

The Central Lead.

For the central lead, the patterns were much the same as the occipital. As in the 12 second intervals, initially, the correspondence between the patterns in occipital and central leads is not complete.

In subject 130, whose occipital record I have given very fully, alpha activity occurs in both leads as early as the second interval. In figure 11, further examples from this subject's records are given to demonstrate the


central lead
2
occipital lead
cent.
5
occ.
cent.
20
occ.
cent.
subject 119
FIG 12
35
occ.
cent.
41
occ.
cent.
53
occ.

correspondence.

Interval Two: The occipital record has already been shown in figure 10, the central recording during the same interval is shown. A low alpha ripple is visible in much the same position as in the occipital record. The very fast activity in this lead is less.

Interval Seven: The upper line of record is from the central lead, and the lower from the occipital. The alpha activity in the central lead is relatively small, and does not completely correspond to that of the occipital lead.

Interval Eight: The correspondence is much more close, and the amplitude of the alpha rhythm, much more nearly equal in both leads. The closeness hereafter increased.

Interval Twenty: This illustrates the high degree of similarity. This continues, despite the non-standard intervals, right to the end of the experiment.

Interval Twenty-eight: which follows a non-standard interval, and interval seventy-nine, from the end of the experiment, have been included to illustrate this.

Over all subjects, the correspondence was much the same. In subject 119 the relationship was a little more loose, and interesting for that reason.

Interval Two: There is very little alpha activity visible in either lead.

Interval Five: Alpha activity is present in the occipital lead at the centre of the interval. In the central lead, this burst is not mirrored in anything more than a ripple at the same frequency. Alpha activity is also visible in the

central recording at the begining and end of the interval, again with a low amplitude. In general, the change in the central lead is to depress the large slow activity and the fast spikes of interval two, and the amplitude of the alpha rhythm to progressively increase.

Interval Twenty: The relative amplitude has increased and, in parts, is greater in the central than the occipital. The central lead shows a node at the mid-point which is not so easily seen in the occipital. It is fairly common to find the alpha in the central lead of greater amplitude than that of the occipital lead, but it is usual, that the part of the pattern in the occipital lead with the largest amplitude, is also the part in the central lead with the greatest amplitude.

Interval Twenty-eight: Alpha activity in the central lead is seen in the first half of the interval and the node is visible, but the largest amplitude of alpha waves occurs after the mid-point. This foreshadows a change in the balance of the activity in the occipital lead, to the second half, in interval 41. The occipital record is similar to that of interval 20. Agreement is usually closer than this, even with this subject.

Interval Forty-One: The respective amplitudes are different but the pattern is much the same.

Interval Fifty-three: The first occurrence of the final pattern in the occipital lead is seen. Three main bursts are present, one in the centre of the first half of the interval, the next in the centre of the interval, the third

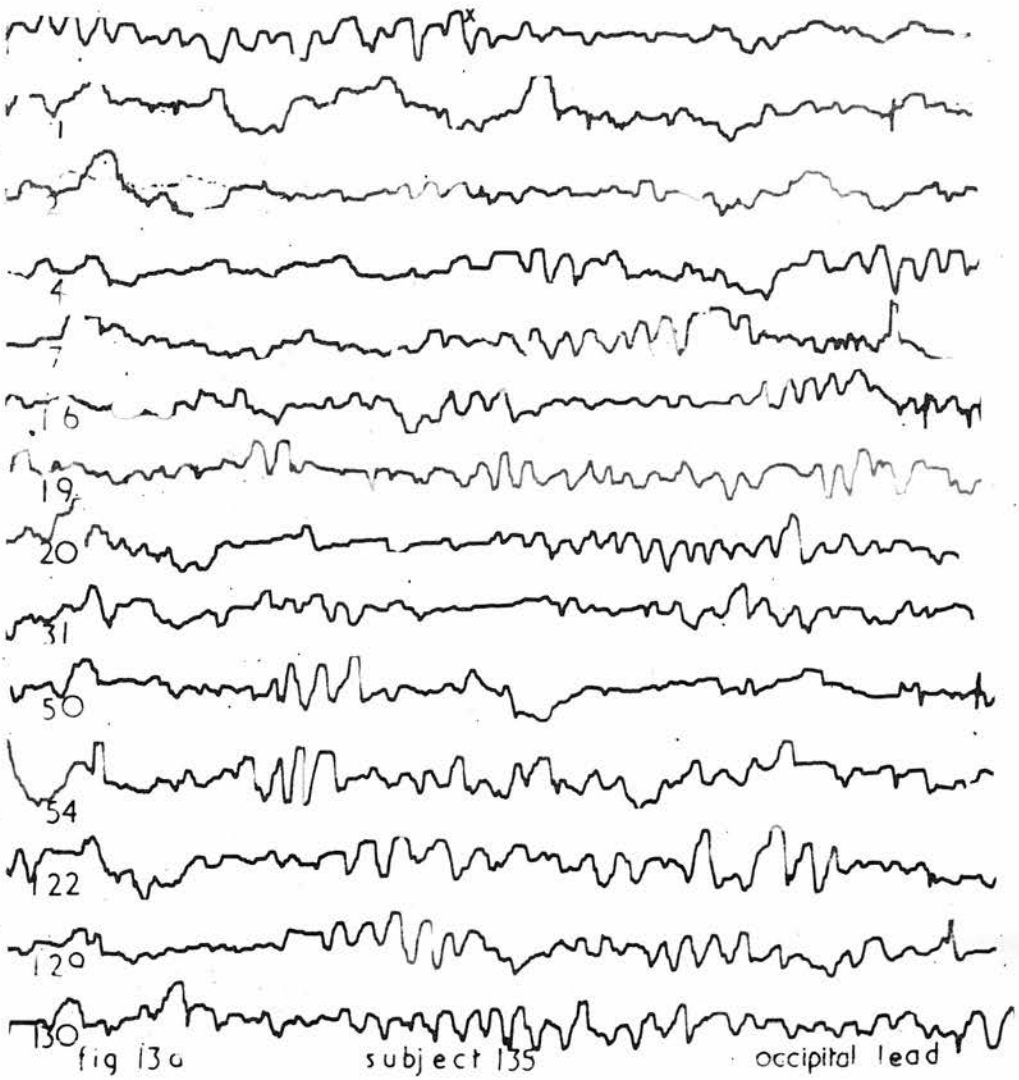


fig 13a subject 135 occipital lead

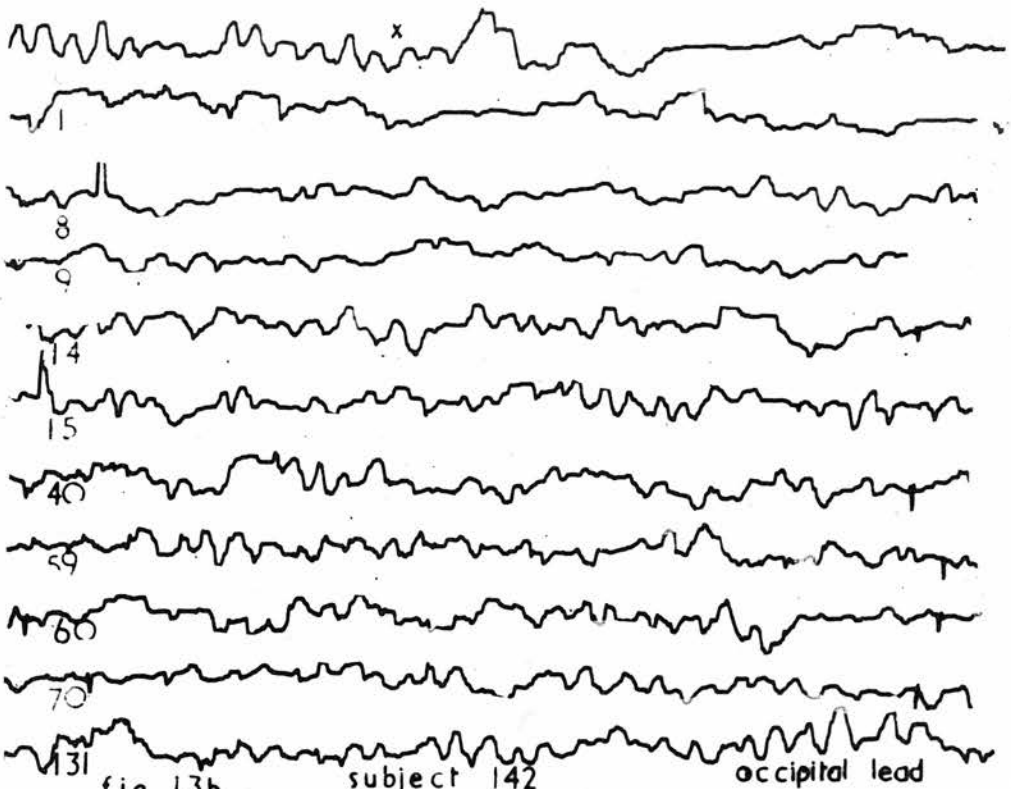


fig 13b subject 142 occipital lead

FIG 13

1 second 50 μ volts

in the centre of the second half of the interval. The greatest amplitude occurs in the latter burst. In the central record, the high amplitude is in the centre. Two or three intervals later, these two patterns became equated, with the largest amplitude in the interval in both leads.

c) Standard Interval of Four Seconds.

Figures 13 to 16 illustrate the results.

In figure 13a, the record of subject 135 is treated in the usual way, to show the development of the patterns.

The first line is the record of the occipital lead with eyes closed initially, and with the instruction to open the eyes given at x. With the eyes closed the alpha activity is average, and blocking is seen to occur after the instruction.

Interval One: No burst of alpha rhythm is obvious, but some 9.5 per second waves are present.

Interval Two: A small burst of activity is seen in the centre of the interval.

Interval Four: The centrd burst has become clearer i.e. raised in amplitude, and a burst starting three quarters of a second before the end of the interval, and lasting half a second at the same amplitude, is present. The bias of alpha activity is definitely towards the second half of the interval.

Interval Seven: The centre burst is extended, starting just after the mid-point of the interval and lasting about one second. The same pattern persists over the succeeding intervals.

Interval Sixteen: Alpha rhythm is seen for the first time at the begining in a rather broken series of waves which block at the mid-point of the interval. The part of the interval corresponing to the burst in the previous intervals shows only a low ripple. A short burst is also seen at the end of interval sixteen, terminating before the end of the interval.

Interval nineteen: The pattern changes to one of irregular alpha activity spaced over the whole interval, with most in the second half. There is no clear evidence of a node. This pattern is not seen in the next few intervals.

Interval Twenty: There is a regression to the pattern in interval seven, and the next advance is not seen until Interval Thirty-one.

Interval Thirty-one: Alpha activity present to equal amounts in each half of the interval, with a node, or drop of alpha, at the centre, is the next advance.

Interval Fifty: A burst in the first half of the interval was the sole evidence of alpha activity, and shows the next change. The amplitude is considerably increased.

Interval Fifty-four: This showed the next new pattern, which is an extension of the alpha activity over the remainder of the interval, following the large amplitude burst at the begining. There is no evidence of a node. The pattern did not advance again during the experiment proper. The whole sequence was repeated after the last non-standard interval without a break. No further advances were made until -

Interval One Hundred and Twenty Two: Alpha activity was observed, mainly in two bursts of increased amplitude occurring just before the mid-point, and about half-way through the second half.

Interval One Hundred and Twenty Nine: Clearly, separate bursts with a node at the mid-point, are present.

Interval One Hundred and Thirty: This was the first, and only time, that this subject showed what was the fairly common final pattern for subjects, with the 12 second interval.

In figure 13b, the blocking was complete when the eyes were opened to the instructions given at x. No alpha activity is observable in the first seven intervals.

Interval Eight: A ripple at alpha frequency can be seen in both halves.

Interval Nine: The amplitude is slightly increased.

Interval Fourteen: Alpha activity occurs in two bursts.

Interval Fifteen: This shows a slight increase in amplitude.

This pattern persisted until:-

Interval Forty: A burst of raised amplitude appeared in the first half of the interval for the first time. No advance was observed from this until interval Sixty, though in Interval Fifty-nine; the burst can be seen to have extended, with the largest amplitude waves earlier than in interval forty.

Interval Sixty: This shows an increment in the alpha activity in the second half of the interval, whilst that, in the first half, is decreased in duration. On continuing the experiment after the 68th interval, the pattern still persisted.

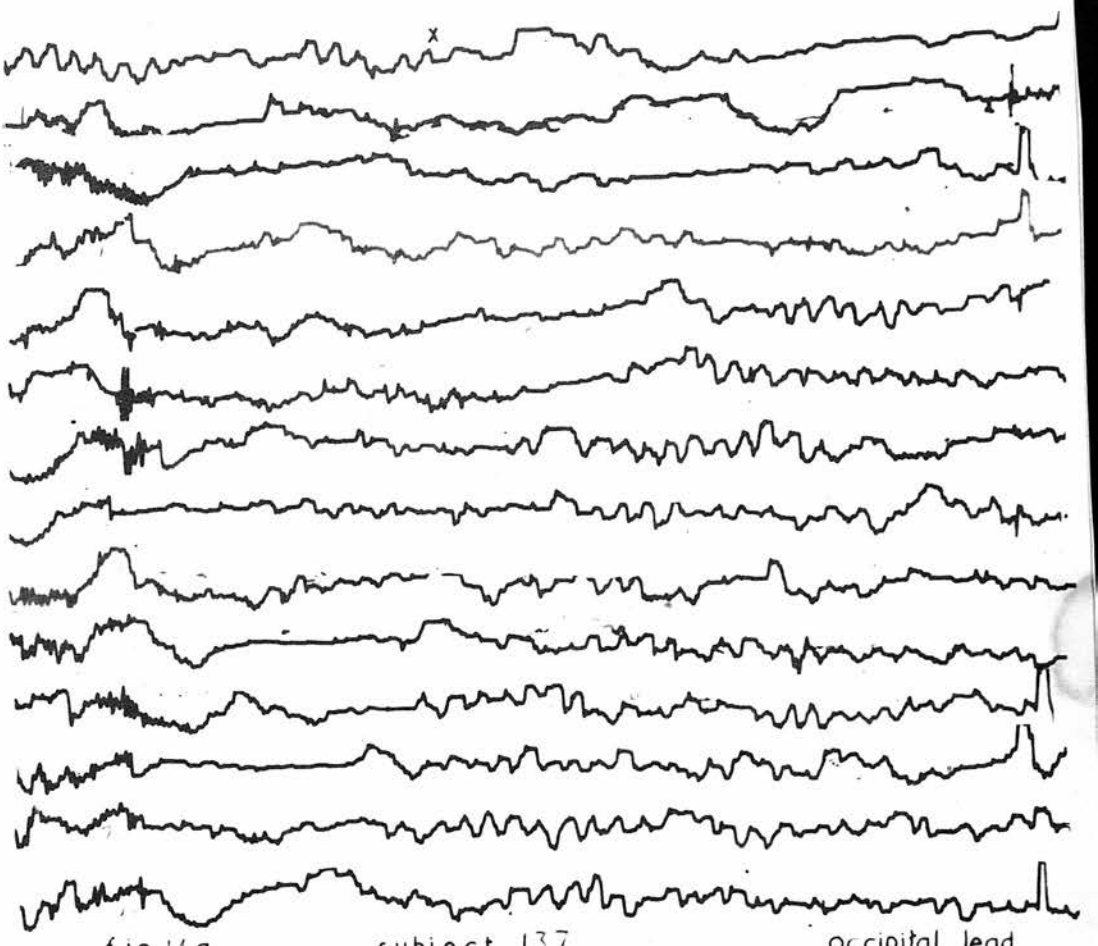
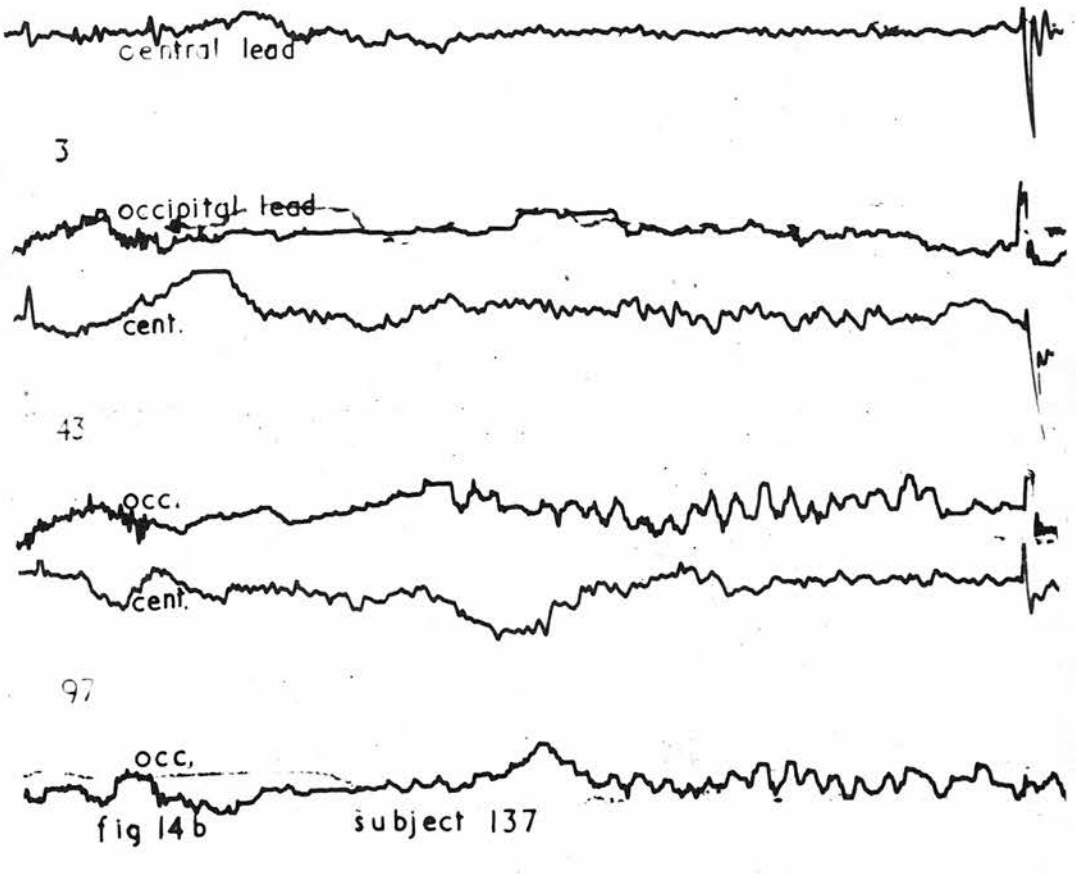


fig 14a
subject 137
occipital lead
1 second
50 μ volts

FIG 14


central lead
3
occipital lead
cent.
43
occ.
cent.
97
occ.
fig 14b
subject 137

Interval Seventy: This shows an increase in the regularity of the alpha activity, but not of the amplitude.

Interval One Hundred and Thirty One: The next and final change occurred. An alpha burst is seen over the mid-point and again, later in the interval. There is a fairly high percentage time of alpha over the whole interval.

Over the experiment proper, the first 68 intervals, the patterns could be regarded as primitive, compared with those developed during the experiment with twelve second standard intervals. The general effect is of increased tension in the subject and consequently a lowered duration and level of alpha activity.

In figure 14a, a fair amount of alpha activity, recorded with the eyes closed, blocked completely, after the instruction given at x, to open the eyes.

Interval One: Consisted of small, fast and large slow waves.

Interval Two: The fast activity persists, but signs of 11 per second waves occur in the last second of the interval. Such a pattern persisted with no increment in alpha activity until -

Interval Eighteen: There was a slight increase in amplitude and a move to an earlier position in the interval.

Interval Twenty: This showed the first spindle of alpha activity, once more, late in the interval. As a result of the disturbance from interval twenty-one, no alpha activity was observed in intervals twenty two and twenty three. The pattern, similar to that of interval twenty, appeared next in

Interval Twenty-four: The duration of the burst was slightly extended, and the amplitude of the very fast activity also

increased a little in this interval. It is interesting to find that this fast activity decreases in amplitude over the mid-point of the interval.

Interval Thirty-four: The burst of alpha rhythm has increased in amplitude and duration, and has once again moved forward in the interval, though not so far as in interval eighteen. No further advance is noticeable until interval fifty four.

Interval Fifty-three: Is included for comparison. There is an indication of alpha activity starting one second after the begining of the interval.

Interval Fifty-four: This is repeated, with the burst of the second half of the interval becoming shortened in duration and moving slightly forward. No alpha activity is visible at the mid-point. This advance was not substantiated.

Interval Sixty: This shows a repeat of the most common pattern, that seen in interval twenty four. The experiment was continued as before, after the 68th interval.

Interval Seventy-three: This shows a change of pattern, A burst over the mid-point of the interval is visible, together with one in the centre of the second half of the interval.

Interval Seventy-four: The pattern is not so well marked, but the main burst over the mid-point is visible.

Interval Seventy-five: The pattern is clear. The symmetry of the interval is still biased to the second half, over the whole of which 11 per second activity is visible. No further advance was made from this pattern, except, perhaps, in the reduction of the amount of activity late in the second half interval.

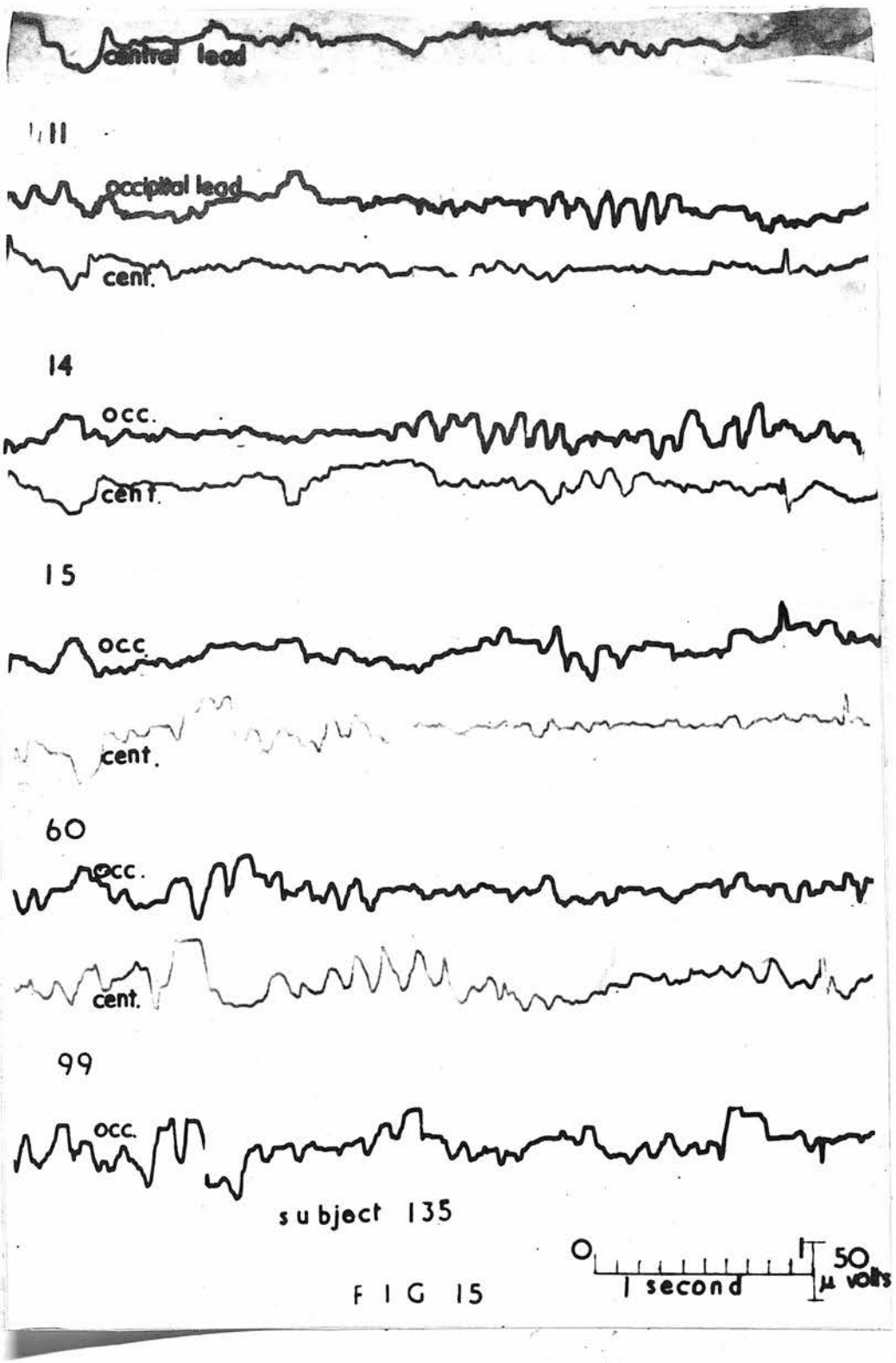

central lead
1/11
occipital lead
cent.
14
occ.
cent.
15
occ.
cent.
60
occ.
cent.
99
occ.
subject 135
1 second
50 μ volts

FIG 15

Interval Ninety-Four: This shows this pattern first. It is seen only three times in the remainder of the repetitions.

In the majority of subjects, activity was observed in the second half of the intervals in the experiment proper i.e. the first sixty eight reactions.

The Central Lead.

It is convenient to consider the central record of this subject first.

Interval three: Low amplitude ripples in the occipital record are accompanied by beta activity in the central lead.

Interval Forty-three: This first showed occasional waves at eleven cycles per second. This level did not change significantly as illustrated by

Interval Ninety-Seven: Much relatively high beta activity is present with a background of 11 cycles per second. The two leads did not correspond closely.

In subject 135, figure 15, the central lead showed the closest correspondence with the occipital lead.

Interval Eleven: This first showed waves at alpha frequency (the first two lines of record).

Interval Fourteen: The low amplitude ripple in the central lead is seen not to have increased.

Interval fifteen: A small increment in amplitude is seen in interval 15 which persists for the remaining intervals of the experiment.

Interval Sixty: Is included as an example of the final

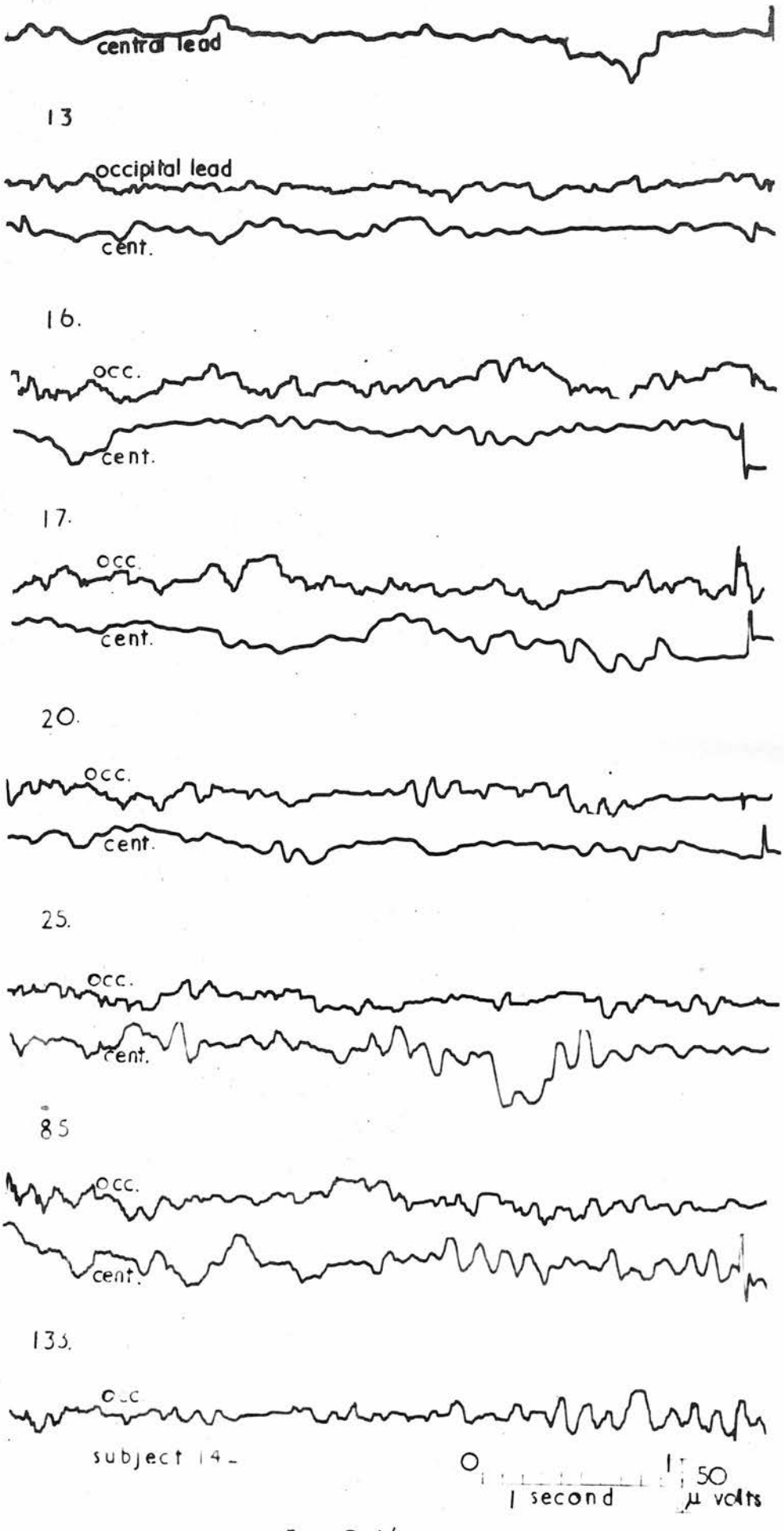

central lead
13
occipital lead
cent.
16.
occ.
cent.
17.
occ.
cent.
20.
occ.
cent.
25.
occ.
cent.
85
occ.
cent.
133.
occ
subject 14 -
0
1 second
50
μ volts

FIG. 16.

order of the alpha activity in the central lead. On continuing the experiment past the 68th interval, one further change occurs.

Interval Ninety-nine: There was an increase in the amplitude of the activity in the alpha range of frequencies, in a large amplitude burst at 8 cycles per second, with rather sharp wave forms. This is in phase with the activity in the occipital region where it occurs in a very much less noticeable form. This burst terminates at the mid-point of the interval.

In other subjects, the correspondence was not so close.

Subject 142, (figure 16), showed no activity in the central lead until, when in

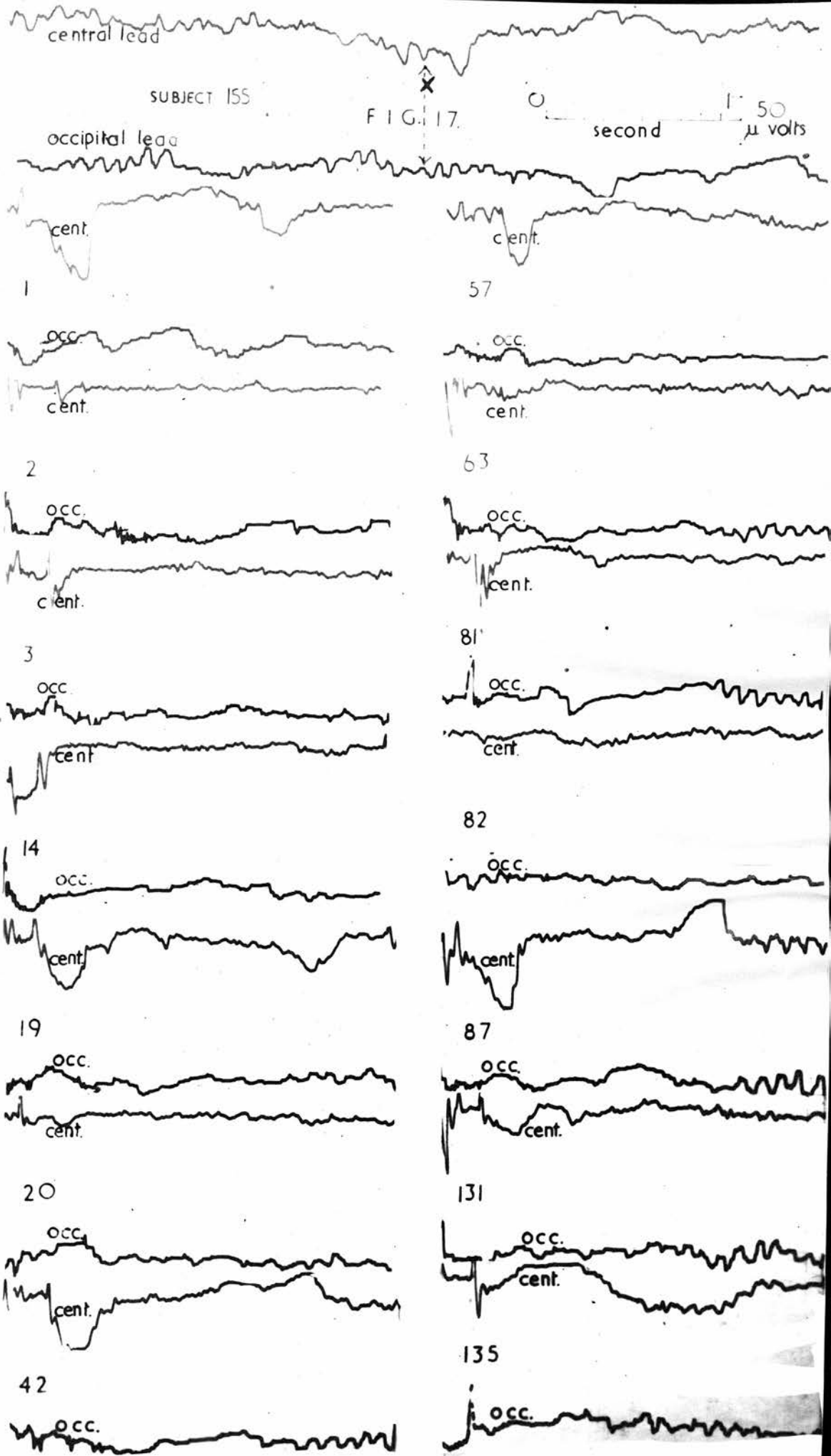
Interval thirteen: A low amplitude ripple is seen. This increases in

Intervals Sixteen and Seventeen: The activity increases in amplitude. In the latter, a burst is seen just before, and another just after, the mid-point in the central record.

Interval Twenty: This is repeated, and a closer correspondence between the leads is seen.

Interval Twenty-five: The correspondence between the central and occipital leads of the second burst in the interval i.e. that in the second half is again good, whereas, that in the first half of the interval, is poor.

This rather loose association in pattern is continued throughout the trials with this subject. It is perhaps interesting to note the variability in one or two


central lead
SUBJECT ISS
FIG. 17.
0
1
50
second
μ volts
occipital lead
cent.
cent.
1
occ.
cent.
57
occ.
cent.
2
occ.
cent.
63
occ.
cent.
3
occ
cent
81
occ.
cent.
14
occ.
cent.
82
occ.
cent.
19
occ.
cent.
87
occ.
cent.
20
occ.
cent.
131
occ.
cent.
42
occ.
135
occ.

more intervals, late in the experiment, and in the repetition.

Interval Eighty-five: Two irregular bursts in the occipital lead are present. The amplitude has increased considerably, and the position of a burst in the central lead, corresponds closely to the position of activity in the occipital lead, but the maximum amplitude of alpha waves in the two leads does not correspond.

Interval One Hundred & Thirty Three: The similarity between the leads is greater, but it will be seen that a burst in the first half interval in the occipital lead has no counterpart in the central lead. The regular burst of four waves just after the mid-point of the interval is paralleled by irregular lower amplitude waves. When the burst in the central lead ceases, the maximum amplitude is reached in the occipital lead, which continues after a larger wave, at approximately 5 cycles per second to the end of the interval. The central record shows increased amplitude over this last short burst.

d) <u>The Two Second Standard Interval.</u>

The pattern was the same for all subjects. Alpha rhythm appeared in the second half of the interval as a short burst of five to six waves. Figures 17 and 18 illustrate the results.

Subject 147, (figure 17), represents well the results from the whole experimental group.

Interval One: This showed (apart from a blink) low fast activity and some slow, 2 per second waves, in the occipital record.

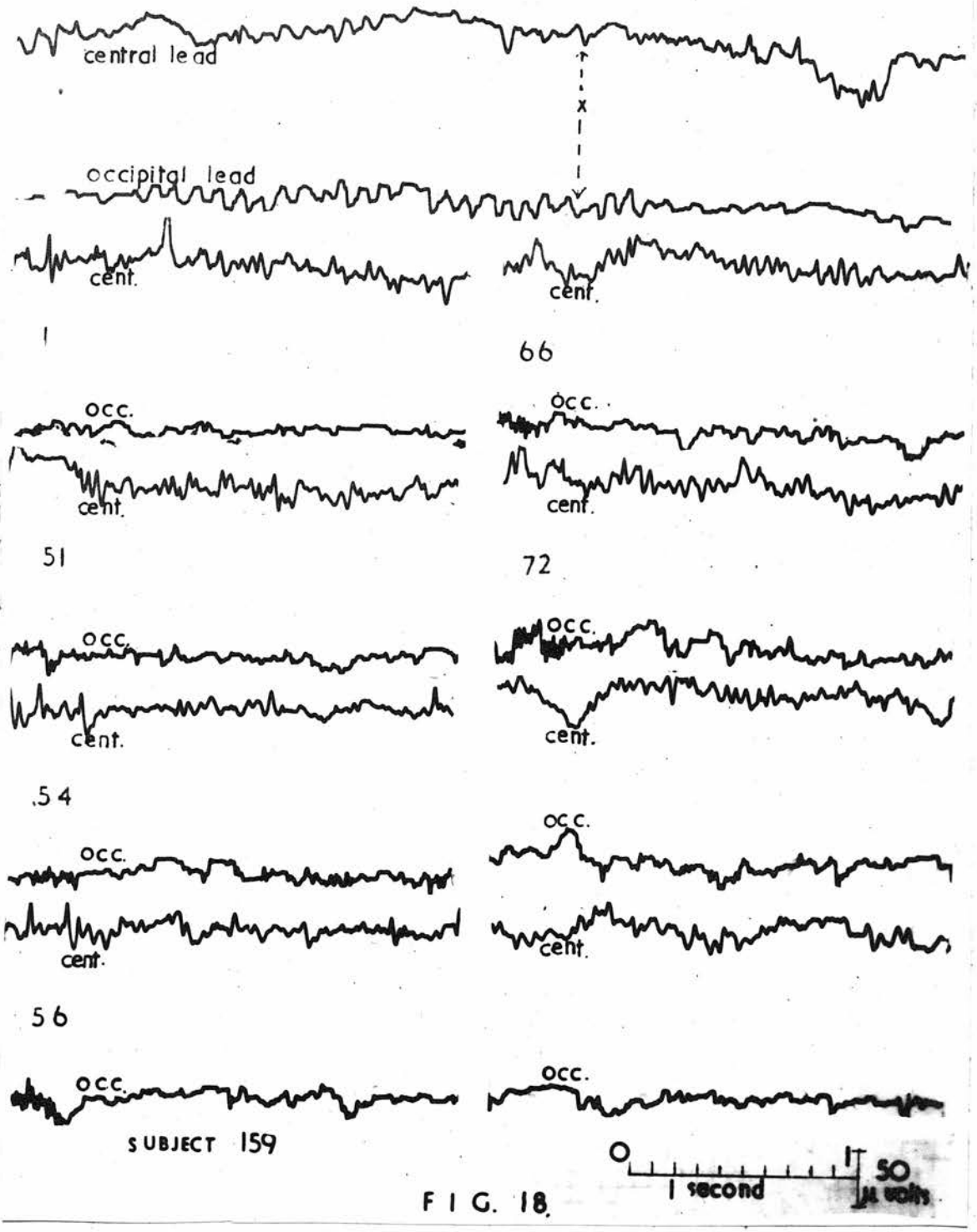

central lead
occipital lead
cent.
cent.
1
66
occ.
cent.
occ.
cent.
51
72
occ.
cent.
occ.
cent.
54
occ.
cent.
occ.
cent.
56
occ.
occ.
SUBJECT 159
O
1 second
50

FIG. 18.

Also in the occipital record are two waves at 11.5 cycles per second at the mid-point of the interval and a suggestion of a 10 per second ripple at the end of the interval.

Interval Two: This does not repeat these waves, and the effect is of a flat record with beta activity.

Interval Three; and succeeding intervals showed no change.

Interval Fourteen: This shows a low amplitude burst of two six per second waves and one 10 per second wave in the second half of the interval in the occipital record. The central lead is passive.

Interval Nineteen: 11 cycles per second waves in the second half of the occipital record are seen. There is a similar ripple in the central record which is nearly obscured by the slow wave at a similar position in the interval.

Interval Twenty: This shows a similar pattern with 11 cycles per second waves in the middle of the second half of the interval. There are also slightly faster waves at the begining of the interval which are probably a perseveration of the burst in the latter half of interval nineteen. The central record shows accassional waves at about alpha frequency. This pattern continued until the end of the experiment.

Interval Fifty-Seven: This is unique for this subject. Activity is seen over the mid-point in the occipital record. This is not reflected in the central lead.

Interval Sixty-three: This illustrates the state of the patterns at the end of the experiment. A clear burst of alpha rhythm

in the occipital record, and one of low amplitude, in a similar position, in the central record, is visible. (As in the experiment with a four second interval, the whole sequence of stimuli was repeated without a break, in order to see the final pattern obtainable in about 130 trials).

Interval Eighty-One: The activity in the occipital lead is increased in amplitude and persists into

Interval Eighty-Two: which, otherwise, does not show alpha activity.

Interval Eighty Seven: Alpha activity is next seen in the central lead of this interval, just before the stimulus, and of moderate amplitude.

Interval One Hundred and Thirty One: This shows the only change in the pattern. The alpha spindle appears earlier in the second half of the interval. The amplitude is reduced before the end of the interval.

Interval One Hundred and Thirty Five: This shows this effect more difinitely, four intervals later. The central lead responds in parallel, and a burst can be seen in the same position.

Differences between subjects produced some records showing no alpha at all. Beta activity occurs to a fairly high degree in the two second interval, in some cases, enough to obscure the alpha activity (for instance figure 18). It is, however, possible that the higher frequency activity also plays a part in the sensory organisation.

With this subject, the amplitude and regularity of

the beta activity tends to, increase as the experiment proceeds.

Interval Seventy Two: This is the two seconds of record following the last stimulus in the test with this subject. The next two pairs of records are of the four seconds immediately following. Following the instruction to open the eyes at x, beta activity appeared immediately. Activity occurs in the bandwidths 11 to 12, 20 to 25 and 40 to 45 cycles per second.

Interval Fifty One: After a number of repetitions, there appears to be an increment in the beta activity over the centre of the intervals.

Interval Fifty Four: The highest amplitude, of 20 - 25 cycles per second activity, remained in the centre of the interval.

Interval Fifty-five: This was short (half second).

Interval Fifty-Six: this does not show the beta spindle in mid interval.

Interval Sixty-six: This shows beta activity in the central lead, in parallel with low amplitude alpha and beta, in the occipital record. The six seconds following stimulus seventy two, show a gradual reduction in the regularity and amplitude of beta activity. It is possible that the beta activity may have been organised in this case, and a few trials required before extinction is complete.

APPENDIX 2

Experiment 2. Detailed description of results.

Figure 23 illustrates the record of Subject 193. From the uncontrolled record with the eyes closed, first interval of the first line, to the pattern obtained in the first intervals of cycles ten and fourteen, a series of stages or developments can be seen. These are, to some extent recapitulated, after the disturbance of cycle eleven.

Cycles One, Two and Three were closely similar to the uncontrolled interval. Cycle two was omitted for this reason. The first difference is observed in cycle three, when the burst of alpha activity, at the end of the first interval, starts, just under one second later, than in the earlier cycles. Alpha rhythm in a short burst, is also seen earlier in this interval.

In the following cycles, the amount and amplitude in the first interval is seen to vary considerably. The general effect is of the formation of a spindle filling a large part of the first interval, and blocking, before the expected opening of the eyes. On the word "open", a series of waves at alpha frequency are recorded. They are very much less regular in the fifth and following cycles. The alpha activity, when the eyes were open, decreases as the repetitions progressed. Cycle five shows the highest percentage time and also the largest amplitude wave.

The second interval of cycle eleven showed slightly more alpha in the first half, than in most of the second intervals of other cycles. Following the mid-point, when

"close your eyes"
open your eyes"
closed
open
closed
occipital lead
seconds
0
1
2
50 μ volts

FIG 23

the instruction to close was expected, the amplitude of the alpha activity increased. It remained for about three seconds. Although alpha activity appeared in the time during which the eyes normally would be shut, the pattern was not the same as any seen in the first cycles with the eyes closed.

Cycle fifteen showed, in the first five seconds of the first interval, a pattern slightly different from that of cycle fourteen. The alpha occurs more symetrically, and is of a slightly lowered amplitude. In the second five seconds, when the eyes normally are open, the alpha is of the largest observed, and fills a large proportion of the five seconds. It diminishes before the end of the ten second interval. Cycle sixteen was very much the same as that of cycle fifteen. The percentage time of alpha is greater in the first five seconds, and less in the second five seconds, than in the same periods of cycle fifteen.

In this subject, the effect of the non-performance of an expected operation, may be to produce alpha activity with the eyes open, or augment that present, when the eyes were closed. Another explanation of interval eleven is that the alpha appeared in the second five seconds because it was expected that the eyes would be closed, and the attention should, therefore, drop. I prefer the first explanation.

Figure twenty-four shows extracts from two subjects who had a similar percentage time and amplitude of alpha, in the uncontrolled resting state. Subject 213 (figure 24a) showed less activity in the first interval than that of subject 218 (figure 24b), but conisderably more in the second

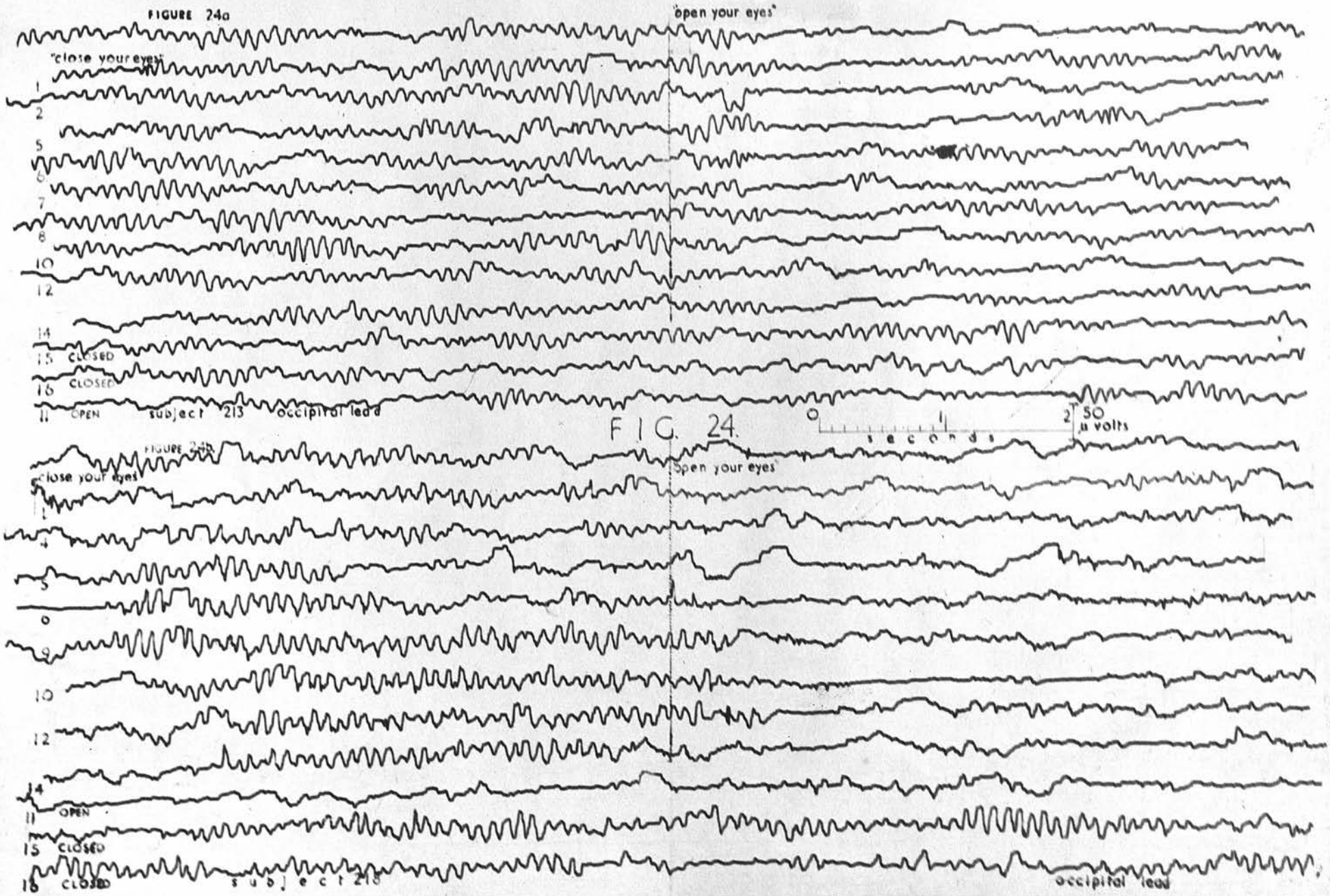


FIGURE 24a
"close your eyes"
"open your eyes"
1
2
5
6
7
8
10
12
14
15 CLOSED
16 CLOSED
11 OPEN
subject 213
occipital lead
0
1
2
seconds
50
μ volts
FIGURE 24b
close your eyes
open your eyes
1
4
5
0
9
10
12
14
11 OPEN
15 CLOSED
16 CLOSED
subject 218
occipital lead

FIG. 24.

interval. The difference becomes more noticeable as the experiments progress.

In figure 24a, the alpha activity with the eyes closed is seen to occupy the begining and end of the first interval. Cycle One. Initially, the balance is towards the end of the interval. This changes gradually, and the spindle in the first two seconds of the first interval, grows in duration. In Cycle eight, the second burst disappears and the first burst fills the whole of the first half of the first interval. The pattern persists to the tenth cycle. The eleventh cycle seems to disturb the pattern slightly, but the "final" pattern appears in the fourteenth cycle.

After the instruction to open the eyes, in the second interval, the usual burst of alpha activity, lasting about six waves, is seen in all intervals, and this is followed by blocking for at least one second. A burst of alpha then follows. This is at a lower amplitude than that with the eyes closed. It is variable in length and duration, but seems to be in one spindle or in two shorter bursts, all blocking before the end of the cycle.

The second interval of cycle eleven is placed at the end of figure 24a. In this, the alpha activity, immediately after the instruction to open the eyes, does not occur. Two spindles of activity are seen in the first five seconds of the interval, the second of higher amplitude, and blocking just before the moment when the instruction to close the eyes is expected. When this does not arrive, a pattern, similar to that of the first five seconds is repeated,

except that the activity, just before the end of the five seconds, is in two bursts. This activity blocks before the end of the interval. The activity in the first five seconds of the fifteenth cycle is rather more irregular than the equivalent in cycle fourteen. Blocking does not occur in anticipation of the expected instruction to close the eyes. Following its non-arrival, a pattern similar to that observed in the first interval of cycle fourteen is seen. The alpha blocks before the end of the interval. Cycle sixteen is most similar to cycle ten in its first few seconds. The alpha occurring mainly in the first two and a half seconds, is of fairly low amplitude at the end of the five seconds. It diminishes in the sixth second and appears irregularly, in a similar position to the spindle, in the last half of the interval. In this subject, the alpha activity is very much more 'available' when the eyes are open, though the percentage time of activity, with the eyes closed, was not as great as has been found in many subjects.

Subject 218, not only showed a similar alpha type with the eyes closed, but also blocked after the first instruction, with a short burst of three waves, four seconds later. The remainder of the interval showed slow waves and beta activity.

The pattern in the first four cycles is similar. It is irregular but of a fairly high percentage time. The first interval of cycle five shows the first definite spindle in the first half. This extends in cycles six, seven and eight until in cycle nine, it fills the whole first interval,

time

nd, for the first, is seen to persist into the second interval. Cycle ten is similar as are twelve and thirteen. Cycle eleven does not seem to disrupt the pattern. In Cycle fourteen, alpha blocks once more before the instruction to open, but, this time, slightly before it.

In the second intervals, more beta activity is seen with some waves at alpha frequency, but with no bursts after the first cycle.

The second interval of cycle eleven, similarly showed very little alpha activity, nor was alpha rhythm visible after the first five seconds, when the instruction had not arrived. The first five seconds of cycle fifteen, was similar to that of cycle fourteen. The alpha is reduced in amplitude just before the moment when the instruction to open the eyes was expected. The expected instruction did not occur, and a burst of alpha starts immediately, which leads, by lower amplitude waves, into a spindle, centrally placed in the second five seconds. Cycle sixteen did not mirror cycle fifteen very closely. The first five seconds is fairly similar, one difference being in an increment in the activity in the first two seconds. The second five seconds is totally different. Alpha is seen in a few single or double waves until the last second, when a burst of moderate amplitude is seen. In this subject, the instruction to open the eyes stops the alpha almost immediately in the first few cycles, and only later, does the instruction not startle him, and the alpha remains

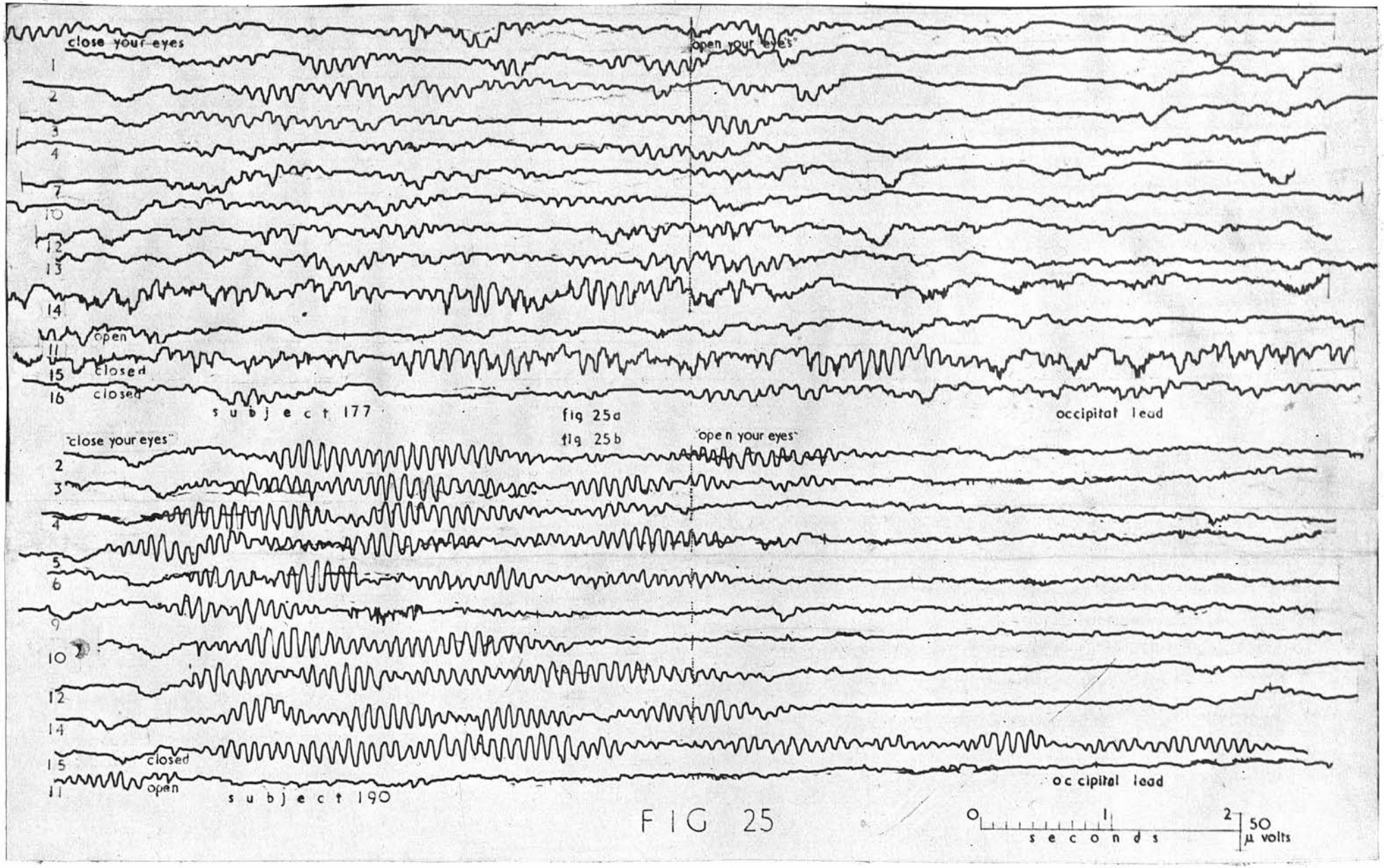


fig 25a

fig 25b

FIG 25

until the eyes are actually open. Figure 25a. In subject 177, the alpha activity seems to be less well controlled. Before the experiment, the activity at alpha frequency was small and irregular. A burst of about ten waves occurs after the first instruction to open the eyes, and, following this, blocking is very nearly complete.

In the first intervals of the second cycle, alpha activity is localised to the centre of the interval, diminishing by the fourth second. In the suceeding cycles, this burst is repeated with a gradually diminishing amplitude. Occasional cycles, for instance number four, show activity immediately before the instruction to open the eyes occurs. Cycle ten shows the most complete pattern, which blocks before the expected instruction. It is composed of a main burst in the centre of the interval, and a smaller one later. As in other cycles, the main burst shows waves at five to six cycles per second, in the centre. The disturbance of cycle eleven, results in the return of a burst, just before the expected instruction, and which does not block before it.

This pattern persists to cycle fourteen. The amplitude of the activity in the last two seconds of the first interval, is appreciably greater than any other seen in this subject.

The second intervals, show almost no alpha activity. That of cycle eleven is no exception. There is, however, a very slight increase of the low amplitude alpha ripple in the second, as compared with the first five seconds.

Cycle Fifteen. shows a repetition of the first interval of cycle fourteen. The large, second burst blocks just before the expected instruction and reappears one second after this moment, (the instruction not having been given). In the second five seconds of this cycle there is an increment of large, slow waves. A burst at alpha frequency appears in the fourth second of the first interval of cycles fourteen and fifteen and is repeated at the end of the second five seconds of cycle fifteen. Cycle sixteen shows a reversion to the original amplitude, and a reduction of the time of alpha activity, in both halves of the first interval. The first five seconds is the lowest. Following the non-arrival of the expected instruction, the longest burst of the interval is seen. This subject's record is puzzling in many respects, as was that of subject 190.

In figure 25b, I have presented the record of the subject showing the highest percentage time and regularity of alpha activity. With the eyes closed before the experiment, persistent alpha was seen at all times. It was, however, disturbed slightly by noise.

In cycle two, the alpha blocked and reappeared before the instruction, and persisted for about one second afterwards. With further repetitions, the main spindle divided into first two, and then three. Later, the amplitude of the last two spindles diminished, whilst that of the first grew. In cycle ten, the pattern is similar to that of cycle two, except that blocking is complete before the instruction, and it remains so. This development, in which the alpha

Subject 208
seconds
occipital lead
50 μ volts
open
closed
closed
open your eyes
close your eyes

FIG 26

activity is eliminated at the instruction, disappears, after the interference of the atypical cycle eleven, in cycles twelve, thirteen and fourteen, whilst the pattern in the first five seconds of cycle fifteen, is once more similar to that of cycle ten.

When the eyes were open, after the first second there is again very little alpha activity. A few waves of low amplitude are visible occasionally, expecially in cycle six. Cycle eleven is no exception, no appreciable change occurs in the second five seconds of the interval. In the second five seconds of interval one, cycle fifteen, the amplitude is reduced, compared with that of the first five seconds. The alpha appears in three bursts, one in the centre of the second half with the other two arranged symetrically on each side, one burst starting when the expected instruction did not arrive, and the other blocking before the next instruction.

Figure 26 is composed of extracts from the record of a subject who was of the predominantly non-alpha type. With the eyes closed before the experiment, the record was mainly flat, with occasional low amplitude ripples at 13.5 cycles per second, and with other waves at 10.3 cycles per second.

When the eyes were opened, there was little appreciable change, as seen in the second interval of the first line of tracing. If anything, there is a slight increase in the activity at the two frequencies mentioned. The first cycle showed the same pattern. Cycle two showed the first change which was of the appearance of a burst of

activity at 13.5 cycles per second in the second ~~second~~ half of the first interval. This was repeated in the next cycle, but in the fourth, five small bursts of varying frequencies can be seen in the first interval. In the fifth cycle, two spindles, at 13.5 cycles per second, and at low amplitude, can be seen symetrically in the first interval. These persist in the sixth cycle, but are of even lower amplitude. The first burst starts slightly later in the interval than in the fifth cycle, and it is retained at higher amplitude in the seventh interval, and the second burst is lost. The pattern is very similar to the second and third cycles. Cycles eight and nine are also similar. Cycle ten, however, is most similar to cycle four, but with extended bursts and larger amplitude. This persists after the interruption of cycle eleven, and the next development is in cycle fourteen where two bursts of fair amplitude are seen to form very much the same pattern as in cycle five. The pattern does not remain in cycle fifteen, the second spindle is not at all visible though the first is slightly extended, if more irregular. This persists in cycle sixteen with increased amplitude and also, a few waves are visible in the fourth and fifth seconds of the cycle, i.e, in a similar position to the second burst in cycle fourteen.

The amount of alpha activity, at ten and thirteen cycles per second, increased steadily in the second intervals as the experiment progresses. In the first six cycles, the balance was towards the later half of the second interval, but in cycle seven, activity is visible with most

in the first three seconds of the second interval. This is repeated in cycles eight, nine and ten. Cycle eleven showed the most activity in a spindle near the middle of the first five seconds of the second interval. Following the moment when the instruction should have arrived, a low amplitude burst is seen, followed later by a few ten cycles per second waves, and later still, waves at five and seven cycles per second are interspersed with faster activity. Alpha in the first cycles blocked before the instruction to open the eyes except on cycle three. There is very little evidence of the burst after the instruction, though some waves, which may be so interpreted, are present in cycles five, six, seven and perhaps fourteen.

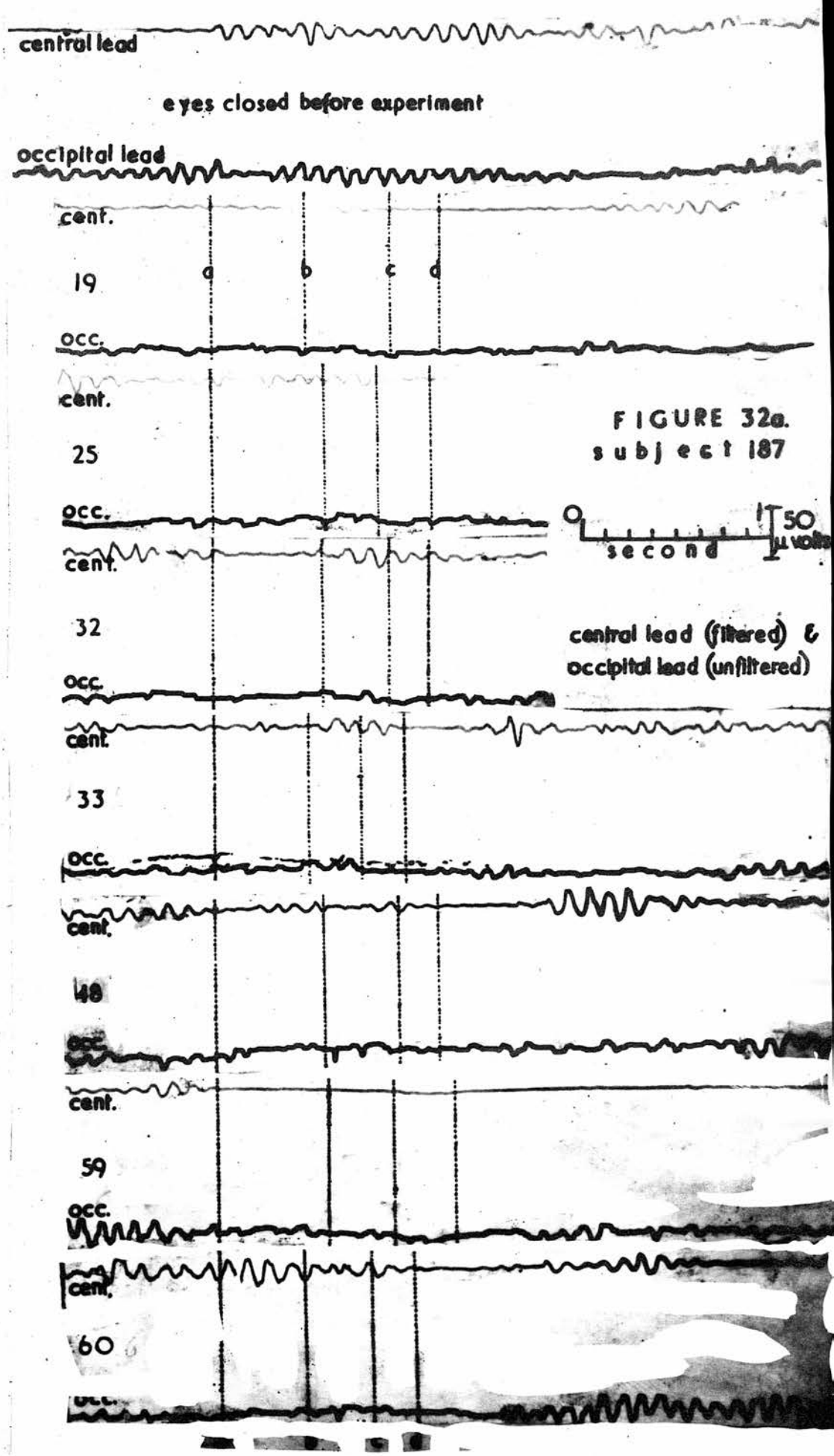
In cycles fifteen and sixteen, when the expected instruction did not arrive, irregular bursts of ten cycles per second activity can be seen over the sixth second of the cycle. These give way to waves at thirteen cycles per second. Waves at ten and thirteen cycles per second are present late in the interval of cycle fifteen, just before the instruction arrived, and to a less extent, in the sixth second of cycle sixteen.

APPENDIX 3.

EXPERIMENT 3.

When the subjects eyes were closed, both the central and occipital leads showed a high amplitude of alpha activity at nine to ten cycles per second. The filter did not entirely remove this activity, and it can be seen in the first line of record in figure 32a. The second line of record was made simultaneously from the occipital lead. The subject's eyes were closed during this time, which was just before the commencement of the experiment. The first appearance of eight per second waves, during the experiment (eyes open), was in the central record in reaction 19 between b and c (over line a in the central record of reaction 19, eleven per second waves are visible).

Eight cycles per second activity, as a preparatory response, occured first in reaction 25 in the central lead between a and b (activity over line a is at ten per second). In reaction 32, waves at eight per second appear over line a, and a fairly high amplitude of activity at this frequency appears in b c. In these reactions, the occipital lead does not give any clear indication of eight cycles per second activity. In reaction 33, however, a few waves at this frequency are visible, no pattern is clear. In the following reactions, the amplitude of eight per second activity increases in both leads. The amplitude of the anticipatory response in the central lead, next increased in reaction 48. Some waves at 10 c.p.s. are also present. The amplitude of activity in the occipital lead is also increased a little


central lead
eyes closed before experiment
occipital lead
cent.
19
a
b
c
d
occ.
cent.
25
occ.
cent.
32
occ.
cent.
33
occ.
cent.
48
occ.
cent.
59
occ.
cent.
60
occ.
FIGURE 32a.
subject 187
second
50
μ volts
central lead (filtered) &
occipital lead (unfiltered)

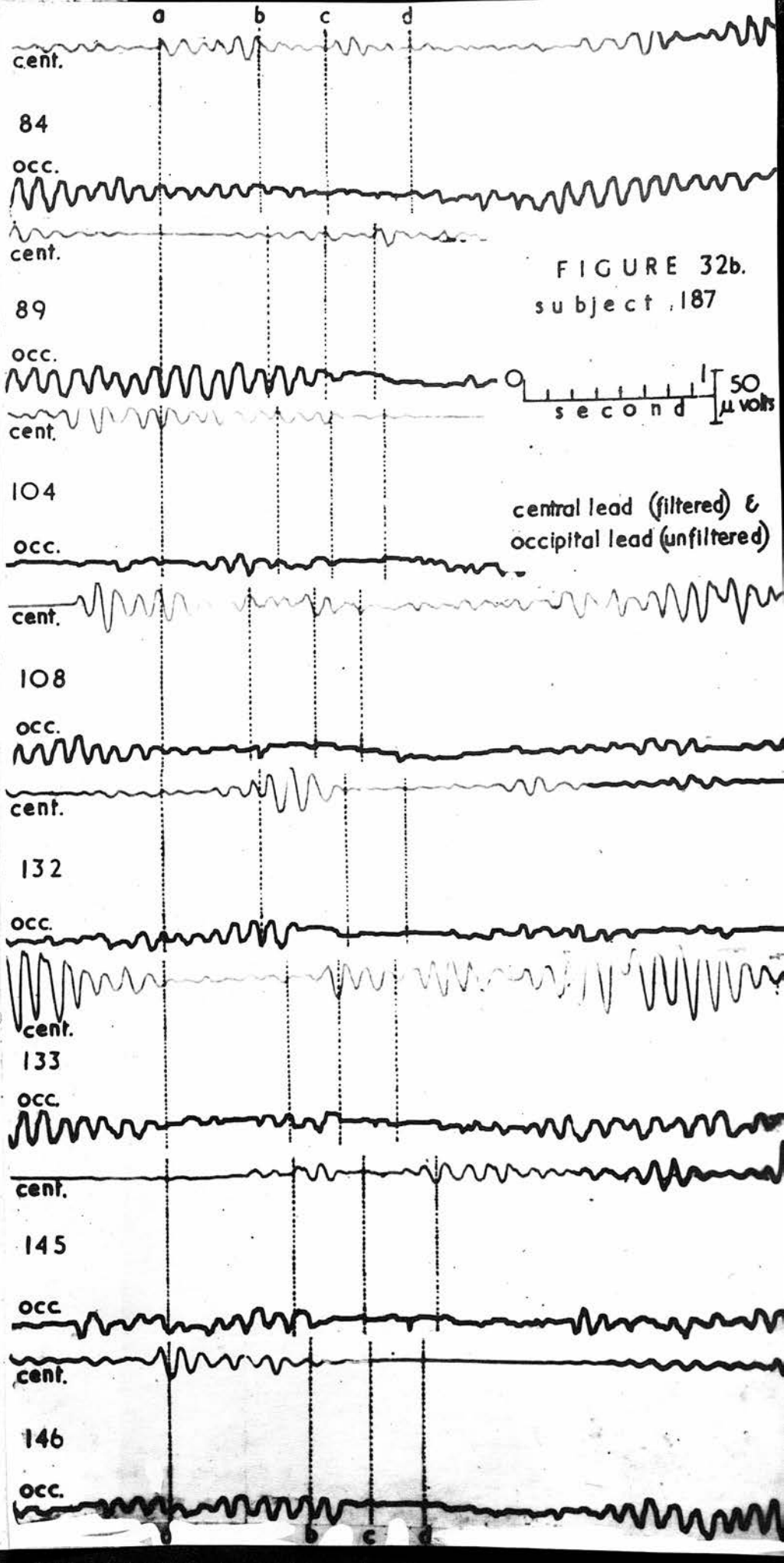


FIGURE 32b.
subject .187

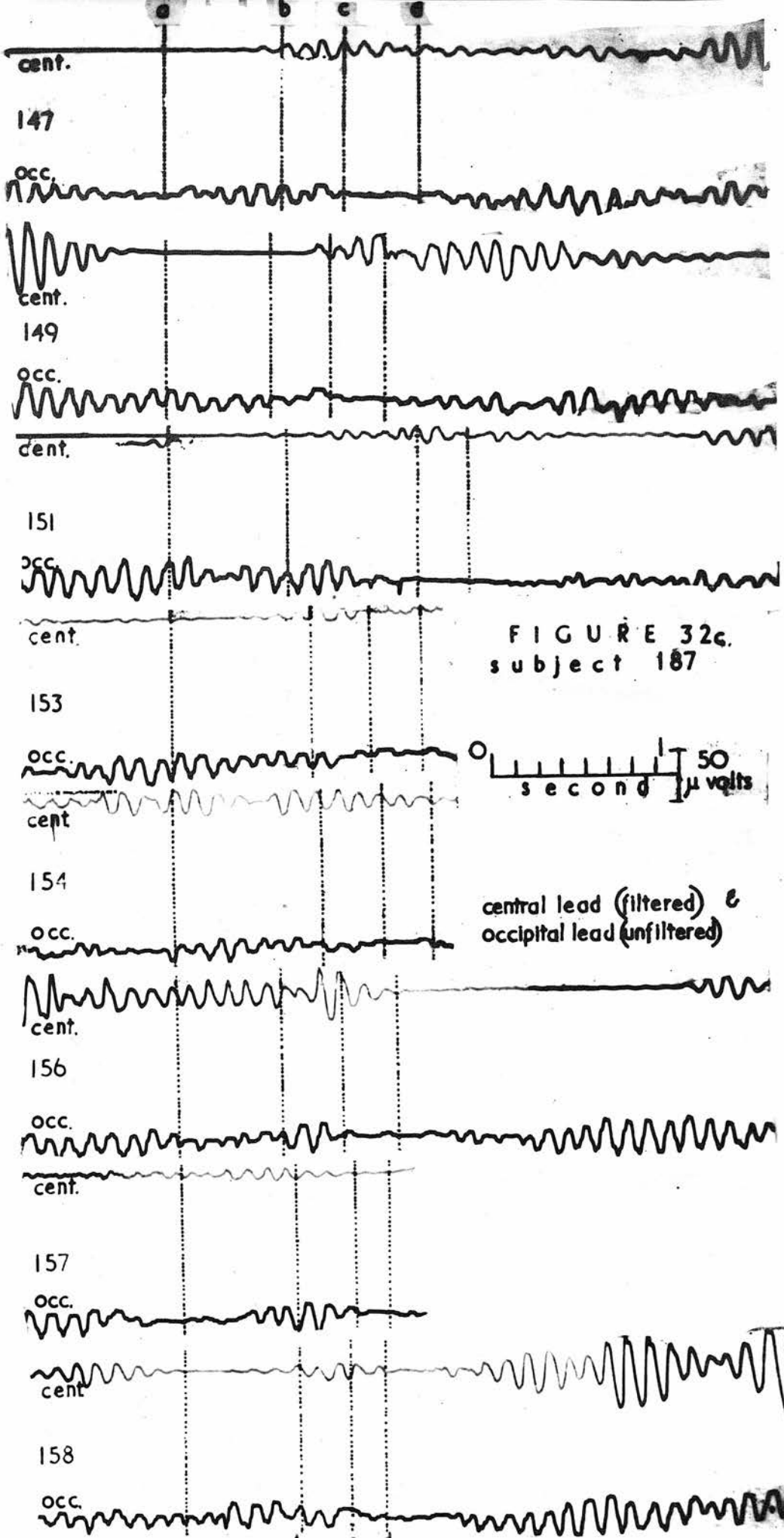


FIGURE 32c.
subject 187

in reaction 48, and considerably increased by reaction 59, where at least one wave at eight cycles per second, at a relatively high amplitude, is present, between the instruction to press the key and the action of pressing it. (i.e. less than one reaction time before a). The pattern of the central lead is similar in reactions 48 and 59 (type 1a). Activity in reaction 60 is of a different pattern, and of a greater amplitude in the central lead.

In the following reactions, the amplitude of activity in both leads increases, as illustrated by reactions 84 and 89 (figure 32b). An anticipatory response is clearly seen in both leads in most reactions from reaction 84.

The first appearance of the third stage of development, in which the patterns is the same in both leads, was in reaction 133. This stage was seen next after forty more reactions. In the intervening reactions, a gradual development in amplitude, and occasional similarities between parts of the record of the two leads in each reaction may be seen e.g. 156, 158, 159 and 161.

The close similarity of the patterns in both leads in reaction 172 is remarkable. The occipital activity leads by perhaps, one wave. The same effect can be seen in the remaining reactions. Differences between the leads never completely disappear. The differences of amplitude and duration of bursts are always present. Clearly, at best, the two leads are incompletely linked.

The greatest single effect of this type of experiment is well illustrated by this subject, namely the marked increase in the last few reactions, compared with the first few, in eight per second activity. This is also well demonstrated

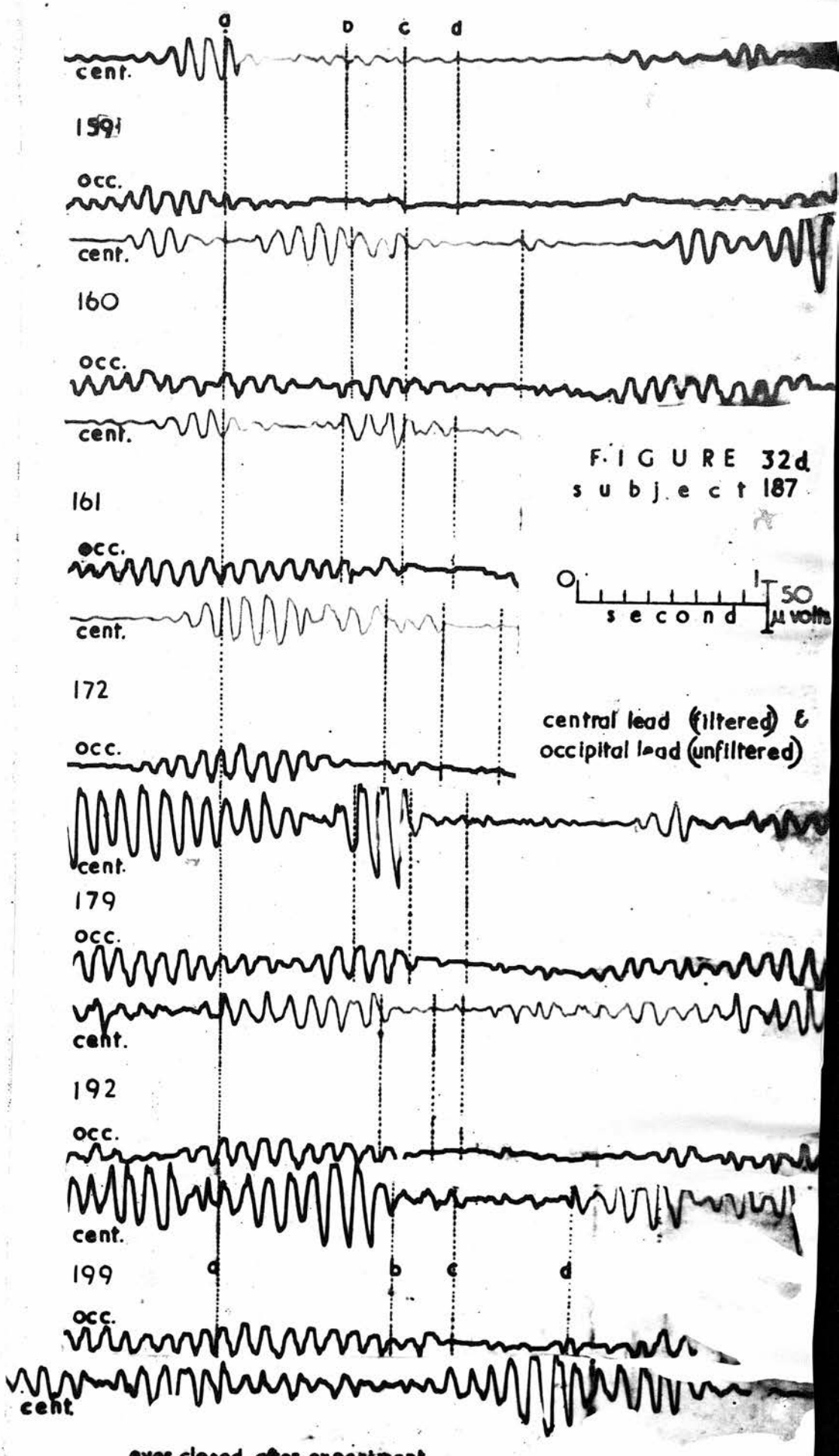


FIGURE 32d
subject 187

eyes closed after experiment

occ.

by comparing the last two lines of record (figure 32d), which were made after the experiment with the eyes closed, with the similar record made before the experiment (first two lines figure 32a).

Appendix 4.

General Experimental Arrangements and Apparatus.

The test session with each subject lasted approximately one hour. The first fifteen minutes were taken up with the preparations. These involved the fixing of electrodes, settling the subject, and testing signals through the amplifiers. The test commenced by instructions to the subject, followed by two minutes with the eyes closed. Throughout experiments one, three, four and five, the subjects eyes were open.

Electrodes. The electrodes were of standard pattern and held in place by a rubber 'net', fixed by tapes under the chin and made comfortable by sorbo rubber pads. They were polarised before each session in the standard manner (Walter 1950a) Monopolar recording was used throughout, and two channels of amplification were available. Active electrodes were placed over the left hemisphere only. Optimum positions were determined in preliminary experiments. The occipital lead was taken from a point, two centimetres above the inion, and the same distance from the mid line. The parietal lead was taken from a point eight centimetres from the occipital, and a line between the occipital and central leads. The central electrode was situated, on an average, thirteen centimetres from the occipital, and was nine centimetres above and two in front of the external auditary meatus. The central and occipital electordes were paired with 'inactive' leads from the right and left mastoid bones respectively. (When the parietal region was recorded, this lead was paired with whichever inactive lead was available). The subject was earthed from a point which was at the intersection of the loci of points equidistant from the two pairs of electrodes, and was usually over the right frontal area.

The Test situation. The subject observed the stimulus from a reclining position on a suitably upholstered metal couch (figure A1). The lamp housing, which was six feet from the eyes, had two compartments open at the front.

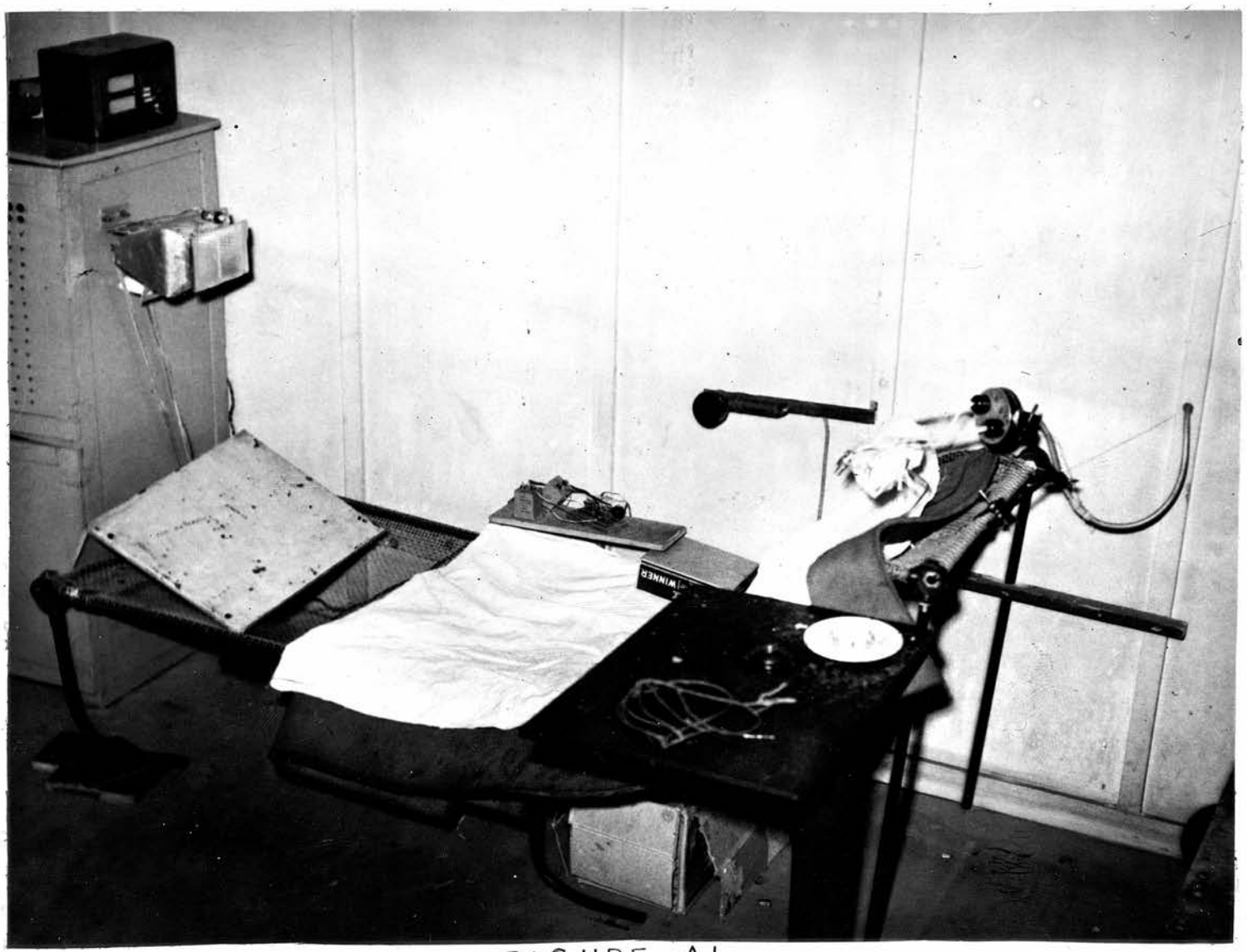


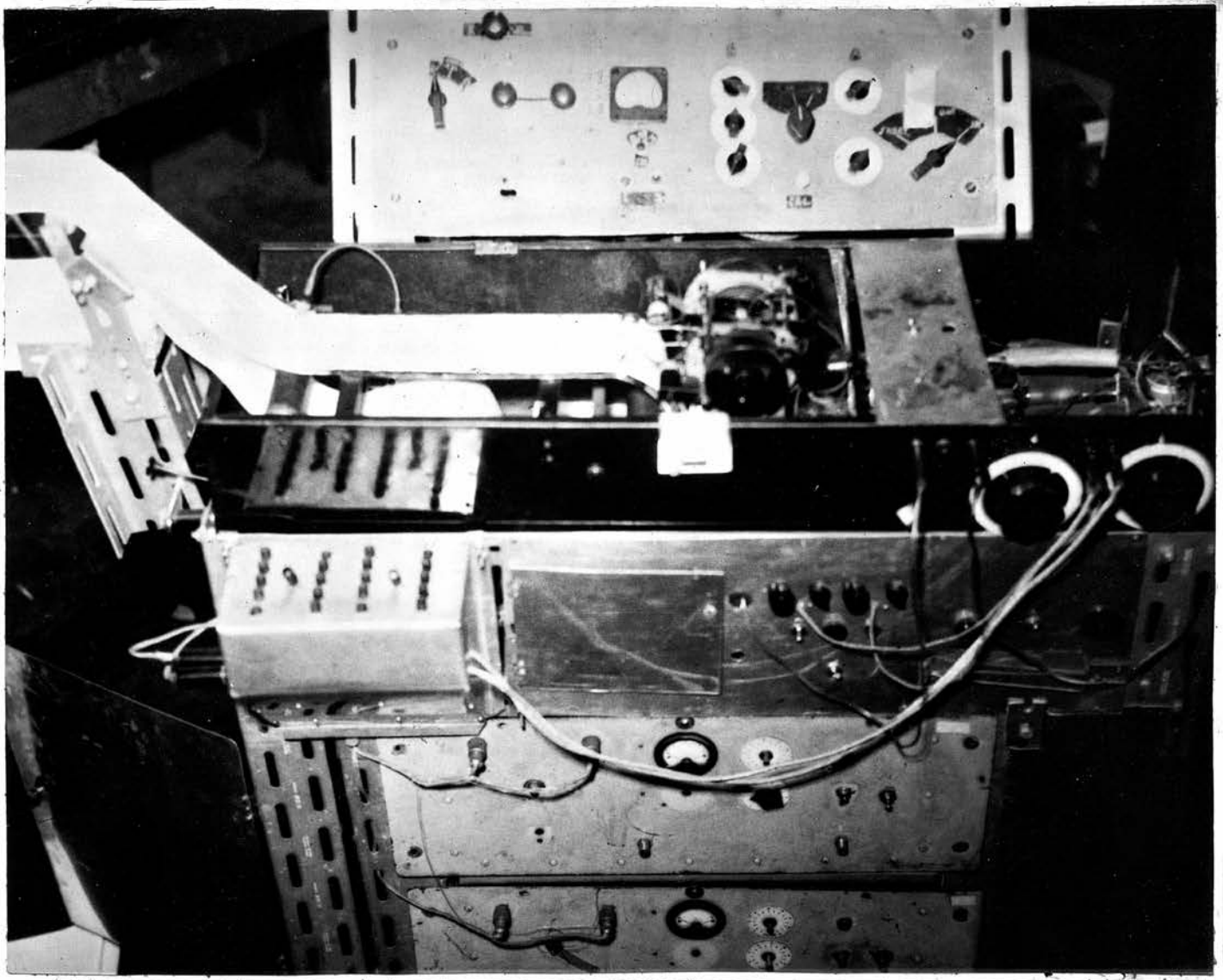
FIGURE A1

In each, a pearl 15 watt bulb was mounted, and the front was covered by a diffusing screen. In all experiments, the signal to respond was, both bulbs illuminated. Times were taken from the moment the bulbs were just visible, approximately ,02 second after the switch was closed. The right arm rested comfortably on a small shelf, the fingers covering the knob of a morse key. Response to the stimulus was made by releasing the pressure on the key. Where a preparatory signal was used, it was the signal to depress the key. In other experiements, where no preparatory signals was used, the key was depressed immediately after the release.

The loudspeaker for intercommunication was situated 18 inches above the lamp housing. The preparatory signal for experiment five, was a 3 volt bulb with a green filter, fixed to the lamp housing above the centre partition. The subjects microphone was hinged to the wall and was moved out in front of the mouth. Crocodile clips were used to connect the electrodes to the input lead of the amplifiers.

Signal Testing. A 50 microvolt 'square wave' was provided by the opening and closing of a switch, tapping off the voltage across 0.1 ohm resistance. (In the maintenance of the apparatus, a ten cycles per second, 50 microvolt signal was used). The amplifier gain was adjusted to give a one centimetre deflection. The resting cerebral activity was observed, and the noise level reduced by adjusting the electrodes, if necessary. The subject was asked to blink, to move his right hand and to swallow, to check for reference, the artifacts from these activities. No artifacts were observed when the subject moved the right hand but otherwise kept still. This usually required a minute or so of practice.

Amplifiers and recorders. The apparatus was constructed with two amplifiers from an Ediswan-Walter "Electrophysiological Amplifiers" apparatus as nucleus. Though now obselete, with careful selection of valves and replacement of some components, these proved serviceable. Switch and calibration



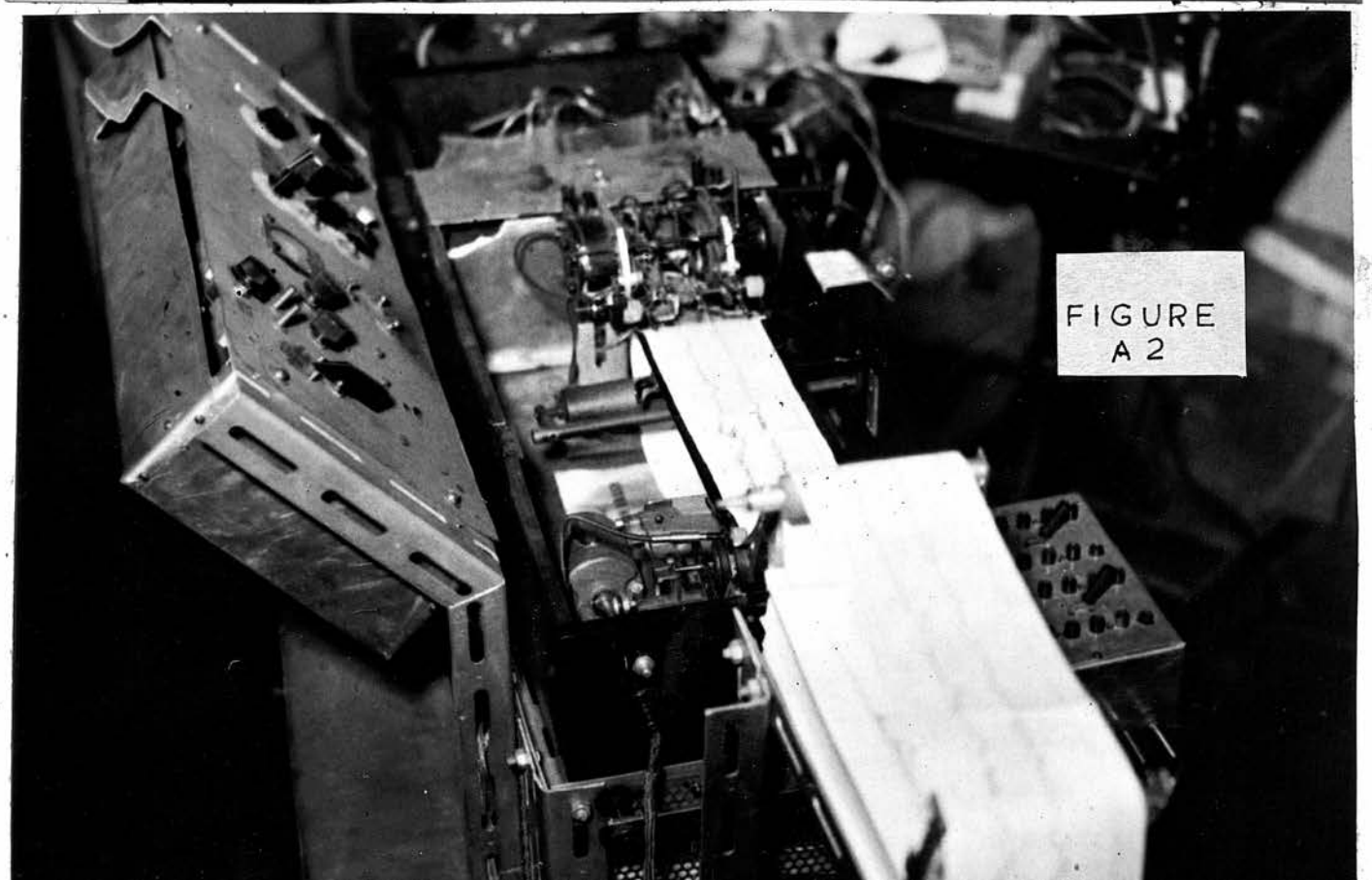


FIGURE
A 2

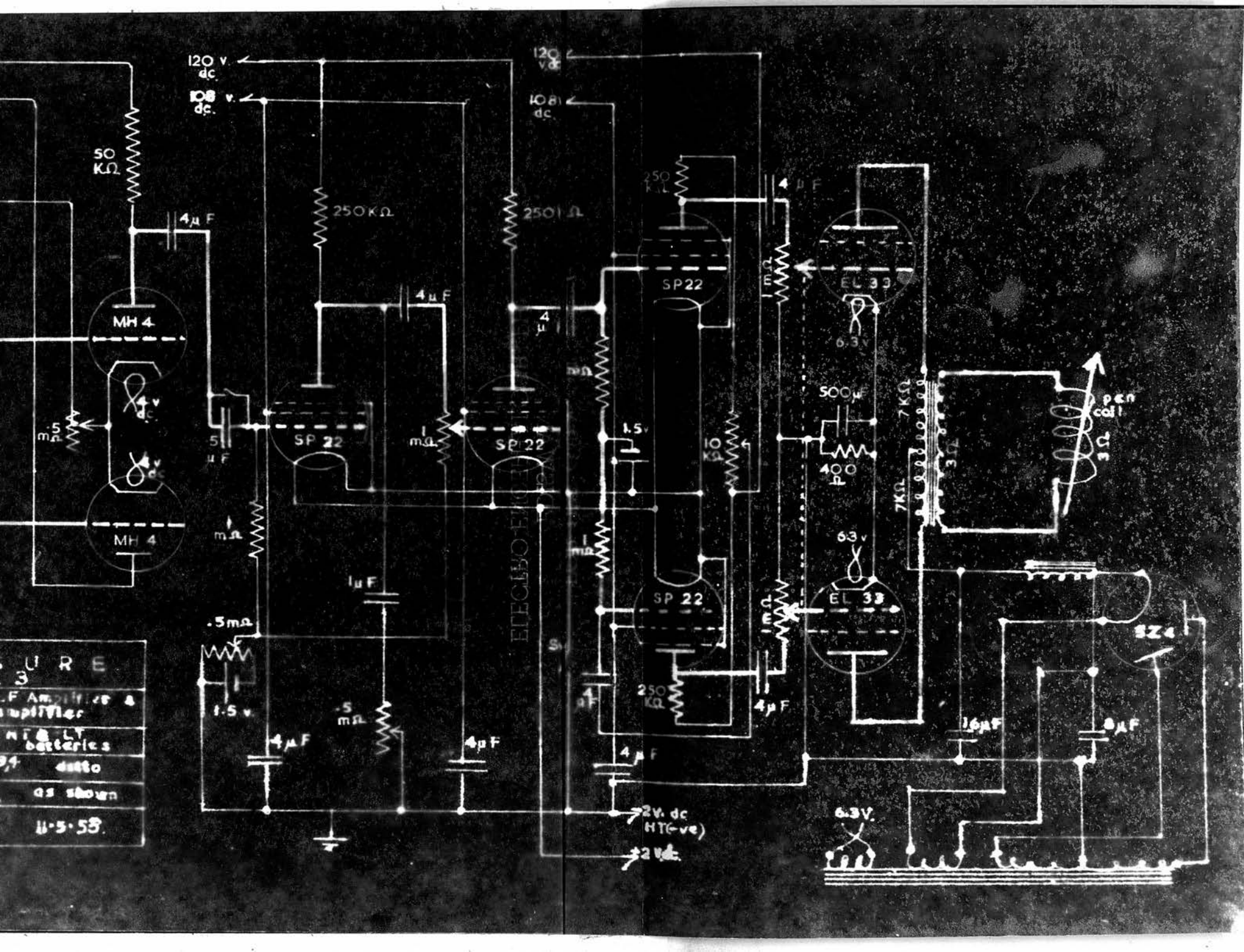
circuits at the input, and power amplifiers, penwriters and paper drive at the output, were constructed, and the whole mounted as a semi-mobile unit. A general view of the unit is given in figure A2, and a circuit diagram of the amplifiers, in figure A3.

The pen "motors" were constructed of loudspeaker magnets and coils. The movement of the latter was transmitted to the pen near its pivot by a piece of drawn copper $\frac{3}{8}$" x $\frac{1}{4}$" x $\frac{1}{100}$" rigidly fixed to the coil and the pen. The pen length was 10.5 centimetres, and the coil fixed to it .7 centimetres from the pivot. With pen deflection, the copper bent slightly, and its thickness was adjusted until the added torque just served to prevent overshoot. The deflection was shown to be linearly proportional to the D.C. voltage applied up to + 1.83 and - 1.79 centimetres deflection, in each pen. The frequency response of the amplifiers and pen writers was approximately flat from 4 to 40 cycles persecond. A peak of responsiveness was seen at 50 cycles persecond. It then detiorated until, at 90 cps., the response was 25% of that at 10 cps. An upper filter was used to attenuate frequencies of 50 cps and above.

The paper speed was 3.7 centimetres persecond. Same trouble was experienced, in the early stages of the experiment, due to friction between the paper, which varied slightly in width, and the guides. Preparation of the paper and increased torque from the motor reduced the effect sufficiently.

The Filter (used in experiment three) consisted of two, 50 henry chokes connected symetrically to earth from each lead situated at the output of the main amplifier, and before the power amplifier. The chokes were shunted by condensors, variable within a small range round eight microfarads, and adjusted experimentally to produce maximum response to an eight cycles persecond input to the amplifiers. It was found that the best setting attenuated signals 0.5 cps to each side of the tuned frequency by 3 decibels (50%).

The Switch Circuits. The oscillator used to provide the regular stimuli and delay of experiments one, three


120 v. dc.
108 v. dc.
50 KΩ
4μF
MH 4
4 v dc.
.5 mΩ
.5 μF
SP 22
250 KΩ
1 mΩ
1μF
.5mΩ
1.5 v.
4μF
.5 mΩ
4μF
ELECTRO-
2V. dc H.T.(-ve)
+2 v dc.
120 v dc.
108 v dc.
250 KΩ
4 μF
SP22
1 mΩ
1.5v
10 KΩ
SP 22
1 mΩ
250 KΩ
4μF
4 μF
EL 33
6.3 v
500μF
400 Ω
7KΩ
7KΩ
pen coil
63 v
EL 33
6.3V.
16μF
8μF
5Z4
U R E
3
F Amplifier &
upliffier
H.T. & L.T.
batteries
ditto
as shown
11-5-53.

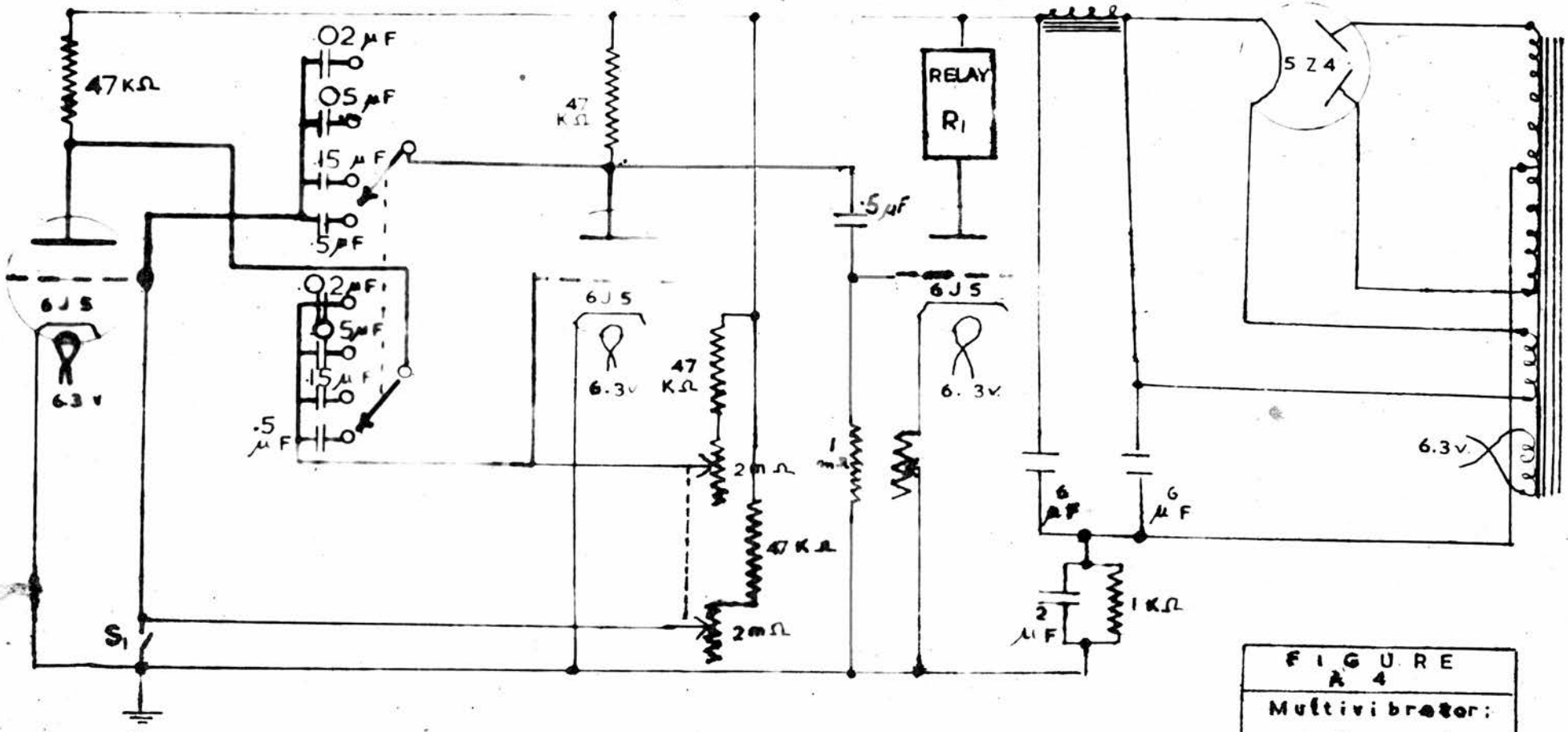


FIGURE A 4

Multivibrator: relay output

and four, was of the multivibrator type, with a relay in the anode lead of the output valve. The circuit diagram is shown in figure A4. Oscillation started when S_1 was opened. The frequency was adjusted coarsely by the ganged condensors, and finely, by the variable ganged 2 megohm resistances in series with them. In the circuit, as shown, the .02 microfarad condensors were replaced by condensors of two microfarads for the very low frequencies of experiment one. The light-dark ratio was adjusted by the cathode resistance of the output valve.

Experiment One. The oscillator was set to a frequency of four times the repetition rate required of the stimulus. In this way, by closing S_1 figure A5 (i) before the end of every fourth cycle, the experimenter produced the standard interval; by leaving S_1 closed, and interval of S/4 was produced etc. In all cases, the moment of onset of the light was determined by the oscillator, and governed, in coarse stages, by the experimenter. The circuit of relay R2, shown in figure A5 (i), was designed so that the subjects response would extinguish the light.

When the subject pressed the key, in preparation for the next stimulus, S_2 was opened. Relay R_1 was operated by the oscillator. When it was energised, marker pen one was released, and the light circuit completed (if S_1 was closed) at the same time, the third set of contacts were closed. When the subject released the key, S_2 closed (and marker pen two operated) the coil of relay R_2 was energised, this closed the two "holding" contacts in parallel with S_2 and opened the light circuit. After releasing the key, the subject depressed it again immediately, leaving the light off and R_2 closed. R_2 was opened in the next half cycle of the oscillation, (Which also opened the light circuit at R_1), thus closing the light circuit contacts at R_2.

Experiment two used the signal from the microphone and amplifier of the intercommunication set to activate the pen coil of one of the oscillographs.

Experiment Three. The circuit, as for experiment one, was used, except that the subjects response controlled only

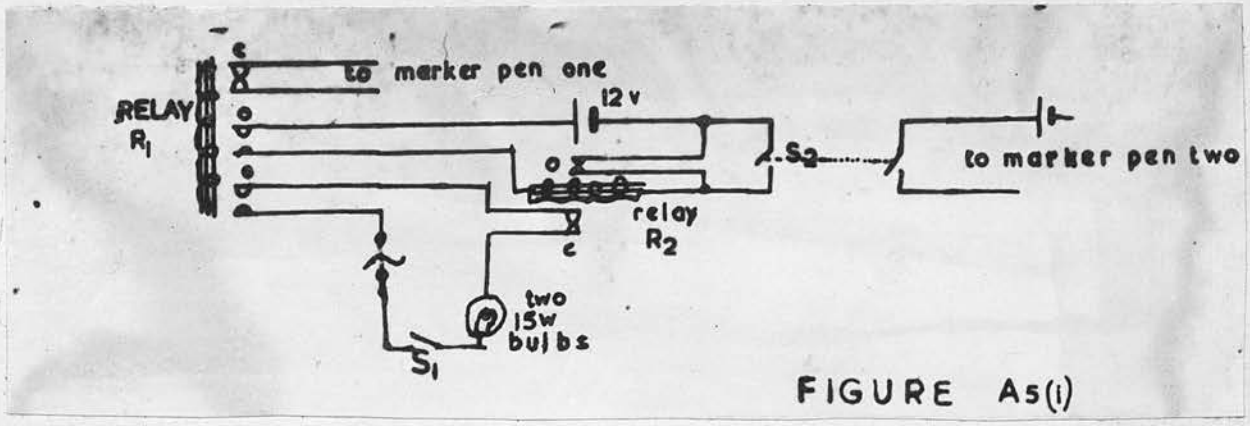


FIGURE A5(i)

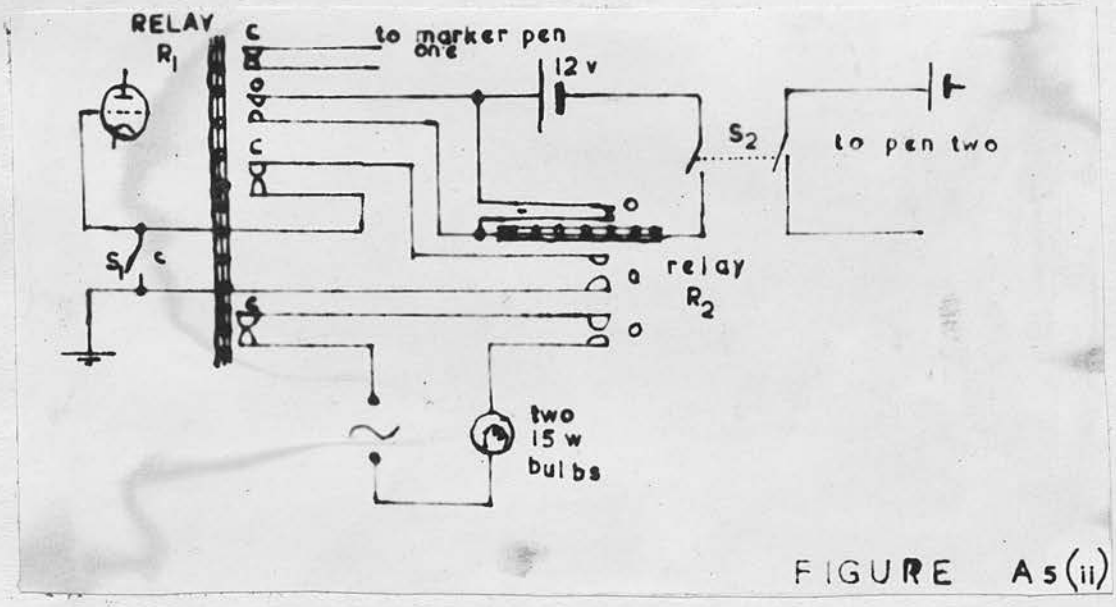


FIGURE A5(ii)

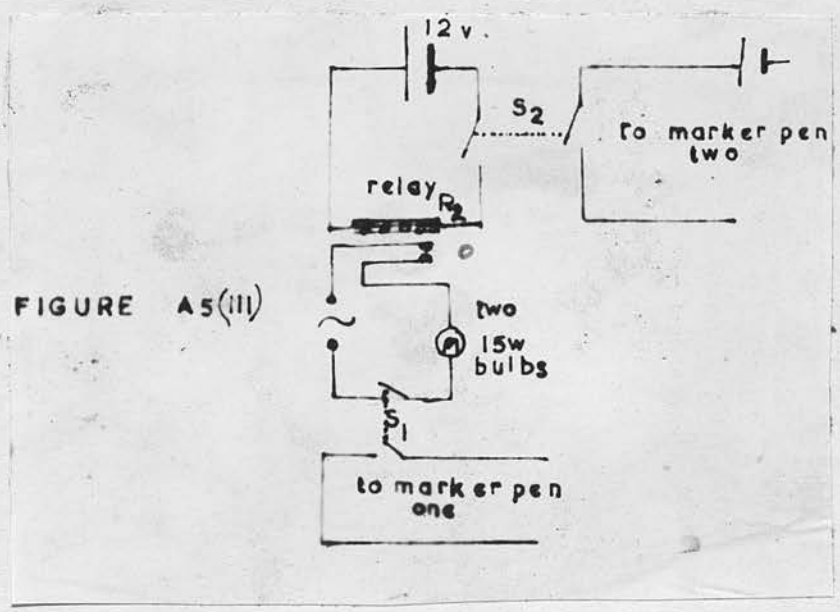


FIGURE A5(iii)

marker pen two, and the relay R_2 circuit was, therefore, cut out.

Experiment Four. For the ordinary stimuli, the circuit figure A5 (iii) was used. The subject pressed S_2, moving the pen and closing R_2. The experimenter closed S_1 (which were the contacts of a relay controlled by the experimenter) thus closing the light circuit, and operating marker pen one. The subject's response released marker pen two and relay R_2, extinguishing the stimulus.

For responses in group one and group two of experiment four, the circuit, as for experiment three, was used, the experimenter closing S_1 for two oscillations only.

For responses in group three, a delay circuit, as illustrated in figure A5 (ii), was constructed, S_2 was closed by the subject. a. The experimenter opened S_1 (grid to earth of oscillator) thus, when R_1 closed relay R_2 circuit closed and was held by the two "holding" contacts. The contacts in parallel with S_1 were opened, as were the pair as part of the light circuit. With the closing of relay R_2, the two pairs of contacts of the oscillator grid and the light circuits respectively, were closed. b. After one half cycle, R_1 opened, completing the light circuit and the grid to earth, switching on the light and stopping the oscillation, respectively. c. On seeing the light, the subject opens S_2 and closes it again. This opens relay R_2 and the whole cycle starts once more. After two stimuli, the experimenters switch, S_1, was closed, and the circuit switched out.

Experiment Five. The circuit of A5 (iii) was used as explained above. The preparatory signal circuit was completely separate, but a switch in marker pen one circuit, in series with S_1, was ganged with the preparatory signal switch. S_1 closed the light circuit and opened the pen circuit simultaneously. The sequence of events was: Preparatory signal on, marker pen one circuit closed. Subject closes S_2, marker pen two circuit closed and relay R_2 circuit closed. S_1 is operated. Stimulus arrives (light comes on), marker pen one circuit opened. Subject releases S_2, marker pen two circuit is opened, light goes off.

The preparatory signal switched off. The cycle is then repeated after the appropriate interval.

All switches and contacts carrying voltage were 'suppressed' and relays were used, in preference to manual operation, to ensure high speed performance where possible. At the onset of the light, a switch potential was occasionally seen in some records. It was usually removed by changing the batteries to the amplifiers, or improving the electrode connections. Occasionally, as a check on the action of the marker pens, the switch potentials were introduced (removing some of the suppressors) for a few reactions.

Appendix Five

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